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OPTIMIZATION OF THE WARKWORTH WATER TREATMENT PLANT FOR CONTROL OF TRIHALOMETHANES

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Optimization of the

Warkworth

Water Treatment Plant for Control of Trihalomethanes

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EXECUTIVE SUMMARY

BACKGROUND

The two main objectives of the study are:

1. Improvement of the water treatment plant performance to meet the new Ontario Drinking Water Objectives (ODWO) THMs guideline without compromising disinfection, to achieve a filter effluent turbidity of 0.1 NTU, and to meet the aluminum operational guideline of 100 µg/L.

2. Sustaining long term performance through skills transfer to plant operating staff and recommendations for plant upgrades where required.

The optimization study was funded by the Ontario Ministry of Environment (MOE), and is a cooperative public/private project between the MOE and RAL Engineering Ltd. By optimizing the performance of their existing facilities, municipalities should be capable of producing water that meets the new THMs objective, and also be capable of improved particle removal and lower aluminum residuals, without requiring costly upgrades.

Trihalomethanes (THMs) are by-products created when the chlorine used in the disinfection process reacts with naturally occurring organics. Trihalomethanes are suspected of increasing the risk of cancer following long term exposure. The Ontario government has lowered the guideline from a maximum acceptable concentration of 350 µg/L, measured as a single occurrence, to an interim maximum acceptable concentration of 100 µg/L based on a running annual average of four quarterly samples.

The associated treatment parameters of turbidity and aluminum residual were also subject of the optimization effort. The ODWO for turbidity is 1 NTU, but current research now indicates that a filter effluent turbidity of 0.1 NTU is needed to provide protection from cryptosporidium. To reduce potential for disease outbreaks, this study will evaluate the feasibility to obtain a turbidity of 0.1 NTU in the filter effluent. The ODWO for aluminum in drinking water is 100 µg /L

The optimization of a water treatment plant consists of evaluating the existing treatment units, conducting laboratory testing to determine the best choice and dosage of the treatment chemicals and making changes to plant operation.

EXISTING CONDITIONS

The original Warkworth Water Treatment Plant was built and commissioned in the late 1960's and was expanded in 1992. Water supply for the plant is taken from Mill Creek, a tributary of the Trent River, which flows into the Bay of Quinte. The expanded plant consists of raw water pumping, chemical feed, in-line static mixer and a Napier-Reid packaged plant which includes three flocculation tanks, one sedimentation tank, and two dual media gravity filters. The plant uses PACl, polymer and chlorine in the treatment process. The Township of Percy owns the treatment plant and distribution system, and operates the plant. The plant is presently operated 6 to 9 hours per day at its rated flow capacity.

A summary of historical data from June 1995 to May 1996 is presented as follow:

Parameters	*Units*	*Raw Water*	*Treated Water*
Turbidity	NTU	0.8 to 5.8	0.1 to 0.9
Colour	TCU	9 to 39	2 to 11
DOC	mg/L	0.5 to 7.5	2.0 to 6.2
pH		7.6 to 8.5	7.3 to 8.4
Alkalinity	mg/L-$CaCO_3$	180 to 227	164 to 212
Aluminum	µg/L	10 to 14	10 to 1900
THM	µg/L		77 to 194

Plant flows are generally:	Average day	308 m^3/d
	Maximum daily flow	488 m^3/d.

PERFORMANCE ASSESSMENT

The average pH of the raw water is 8.2, which is high and would contribute to the high aluminum residual in the treated water.

The raw water turbidity varied from 0.8 to 5.8 NTU. The average treated water turbidity ranged from 0.1 to 0.9 NTU. The turbidity did not exceed the ODWO of 1 NTU but exceeded the operational objective of this study of 0.1 NTU. An option available to improve particulate removal is to optimize the coagulant and coagulant aid dosage through jar testing, and possibly adjustment of the pH of the raw water.

The THMs measured in the treated water at the plant varied from 56 to 170 µg/L, for an average of 116 µg/L. The THMs levels in the distribution system varied from 52 to 230 µg/L, for an average of 125 µg/L. The THMs during the summer of 1997 exceeded the new ODWO of 100µg/L. An option available to reduce the formation of THMs is to stop pre-chlorination of the raw water and post-chlorinate the treated water leaving the filter effluent.

The water samples taken in the distribution system for THMs analysis were quenched with sodium thiosulfate to remove any chlorine residual to stop further reaction between free chlorine and organics. Water samples taken at the water treatment plant for THMs analysis were not quenched, the reason being to simulate the effect of additional contact time in the distribution system.

Based on THMs, colour and TOC analysis performed for the Warkworth Water Treatment Plant, there is some evidence of a relation between the level of colour or TOC in the water and the level of THMs formed. The highest THMs level was measured at a time when TOC was the highest as would be expected.

Additional analysis was performed to evaluate the level of haloacetic acids (HAAs) in the treated water. HAAs are by-products of disinfection with humic substances and may be of concern to human health. Currently, there is no guideline in Ontario regulating the maximum level of HAAs in drinking water. The US Environmental Protection Agency (USEPA) has proposed the maximum contaminant level in the first stage of the upcoming Disinfectants/Disinfection By-products (D/DBP) Rule to be

60μg/L for the total concentration of five HAAs. The five major HAAs are – monochloroacetic acid (MCAA), DCAA, TCAA, monobromoacetic acid (MBAA), and dibromoacetic acid (DBAA). The levels in the treated water at the plant varied from 114 to 141 μg/L for an average of 130μg/L. HAAs in the distribution system varied from 88 to 123 μg/L for an average of 101μg/L. With improved removal of organics through the optimization effort it can be expected that HAAs along with THMs will be reduced.

OFF-SITE AND ON-SITE TESTING

A preliminary screening study was performed on water collected at the plant and sent to the MOE Standards Development Branch. This testing indicated both Alum and PACL performed well, however, the polymer LT27A outperformed the polymer LT35 that was used in the plant. Tests also indicated that LT20 and LT24 were other good choices. Further on-site testing was conducted that confirmed these results. Lowering of the plant flow rate was done to increase residence time in floc tanks and lower the surface flow rate in the settling tank, hopefully improving floc formation and settling. As well, the mixer in the second tank was shut off. The floc produced was much larger and settling improved slightly, as indicated by lower filter influent turbidity than trial No. 1. Further study is recommended to evaluate the impact of shutting down mixers in the first flocculation tanks and lowering plant flow rate.

CONCLUSIONS

High levels of colour in the raw and treated water present higher potential for THMs formation since organics in the water will react with free chlorine to form THMs. Stopping pre-chlorination should help reduce levels of THMs in the treated water below the new ODWO guideline of 100μg/L. It has been more difficult to achieve the goal of 100 μg/L for aluminum residual in treated water. Trial testing to perform pH adjustment of the raw water would be useful in determining its impact on aluminum residual in the treated water. To achieve the high levels of performance that provides the greatest protection against harmful organisms, it is necessary to have precise control over the addition of the treatment chemicals, have good dispersion of those chemicals and to have a continuous readout and record of plant performance. This usually results in the added economic benefit of making the most effective use of these treatment chemicals.

RECOMMENDATIONS FOR PLANT SCALE MODIFICATIONS

The following is a summary of recommended modifications to improve the plant's overall performance.

1. Stop pre-chlorination to the wetwell to reduce THMs formation;
2. Install a new post-chlorine injection system at the filter effluent to provide sufficient contact time in the clearwell for inactivation of cysts and viruses;
3. Modification to the backwash procedure;
4. Stop discharging the waste water supernatant to the wetwell, and discharge it to the creek to reduce the potential for reintroducing cryptosporidium to the water supply;

5. Install on-line turbidimeters for the raw water and the filter effluent to help staff respond quickly to water quality changes;
6. Perform CO_2 full scale trial testing to lower the pH of the raw water;
7. Reduce plant flow rate to improve flocculation;
8. Switch to a more effective polymer.

COST ESTIMATE FOR IMPLEMENTATION

The installation of the post-chlorine injection at the filter effluent was done in the winter of 1998. The equipment required to prepare a polymer solution from a dry powder was purchased in March 1998 and its installation and commissioning is scheduled for late spring/early summer of 1998. The equipment was purchased by the MOE and the cost involved is summarized as follows:

• New post-chlorine injection system at the filter effluent:	$ 4,340
• Manual dry feed polymer system:	$ 5,300
Total cost (Taxes not included):	**$ 9,640**

It is expected that by stopping pre-chlorination this will translate to a potential saving of up to 50% in chlorine cost.

A summary of the cost estimate for the installation of a new piping system to discharge the wastewater to the creek, the installation of in-line turbidity meters and one recorder, and for CO_2 full scale trial testing for pH adjustment of the raw water is presented in Table 9.1. The cost estimate is summarized as follows:

• New piping system for supernatant discharge to Mill Creek:	$ 5,000
• Installation of three in-line turbidity meters and one 3-pen recorder:	$ 9,000
• CO_2 full scale trial testing:	$ 5,000
Total budget cost (Taxes not included):	**$19,000**

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1.0 BACKGROUND

Trihalomethanes (THMs) are by-products created when the chlorine used in the disinfection process reacts with naturally occurring organics (e.g. formed by decay of algae and vegetation) in raw water. Surface water containing high organics also often has high colour levels. The most common forms of trihalomethanes created are chloroform, bromodichloromethane, chlorodibromomethane and bromoform.

The formation of THMs is influenced by several factors:

• Free chlorine concentration	- higher Cl_2	= higher THMs
• Organic content	- higher organic concentration	= higher THMs
• pH	- higher pH	= higher THMs
• Temperature	- higher temperature	= higher THMs
• Time	- normally longer time	= higher THMs

Since the formation of trihalomethanes is associated with the presence of organics in the water, small inland lakes and rivers, which may contain more organics than large clear bodies of water have a greater trihalomethane formation potential, especially during periods of high runoff.

The reason for adding chlorine to drinking water is to kill bacteria and other microorganisms that could cause numerous illnesses. However chlorine use leads to the presence of trihalomethanes and this is a cause for concern. Studies have found an association between high levels of trihalomethanes in chlorinated drinking water, and slight increases in cancer following long term exposure of more than 35 years.

Chlorine has an advantage over other disinfectants in that it persists many hours or for days and provides protection for the entire water distribution system. The benefit to public health of using chlorine as a disinfectant in drinking water far out-weighs the risk to health associated with the low levels of trihalomethanes created as by-products of chlorination.

In order to decrease the health risk from trihalomethanes, the Canadian and Ontario governments have lowered their respective guideline limits from a maximum acceptable concentration of 350 µg/L, measured as a single occurrence, to an interim maximum acceptable concentration of 100 µg/L based on a running annual average of four quarterly samples.

Disease outbreaks caused by giardia and cryptosporidium have been reported with increased frequency over the last decade in Canada and the US. These protozoan parasites (especially cryptosporidium) are more difficult to kill than bacteria with disinfectants, and therefore their removal by physical processes is vital. As a result, Health Canada is now examining the need for stricter standards for particle removal in water plants. The current Ontario Drinking Water Objective (ODWO) for turbidity that applies at the water treatment plant is 1 NTU, but current US research and experience now indicates that a filter effluent turbidity of 0.1 NTU is needed to provide protection from cryptosporidium. In the attempt to reduce potential for disease outbreaks, this study attempted to evaluate the feasibility to obtain a turbidity of 0.1 NTU in filter effluent.

Alum (aluminum sulphate) is the most widely used coagulant because it is effective, readily available, and relatively inexpensive. However, under some circumstances, or if not used properly, its use can result in elevated levels of residual aluminum in finished drinking water. An article was published on facts about human health and aluminum in drinking water (Environmental Science and Engineering Magazine, January 1997). The following is a summary of the major facts presented in the article.

In recent years, increased attention has been focused on possible adverse effects of aluminum in drinking water on human health. Several epidemiological studies have reported a slightly increased incidence of dementia in communities where drinking water is high in aluminum and these studies have raised concerns among the media and public. A number of theories on the causes of Alzheimer's disease have been proposed and are currently under investigation. From what we know at this time, the evidence linking aluminum and Alzheimer's disease is far from conclusive, but we also cannot be sure that there is no relationship. Humans are constantly being exposed to aluminum via food, air, and water. Ninety percent (90%) of aluminum intake is from food. In general, exposure to aluminum from drinking water is very low (below 3%) compared with that from food and drugs. At the present time the ODWO for aluminum in drinking water is 100 ug/L, which is an operational not health related guideline.

Owners of water treatment plants and water distribution systems who provide water for consumption have legal responsibilities, which are shared by all suppliers of food or drink. Owners and suppliers must take reasonable measures to ensure the water is fit for safe consumption.

This optimization study is funded by the Ontario Ministry of the Environment (MOE), and is a cooperative public/private project between the MOE and RAL Engineering Ltd. By optimizing the performance of their existing facilities, municipalities with a conventional water treatment plant (i.e. coagulation, flocculation, settling, filtration and disinfection) in many cases should be capable of producing water that meets the new THMs objective, and also be capable of improved particle removal, without resorting to costly upgrades. The optimization of a water treatment plant consists of:

- Documentation of existing facility.
- Assessment of the performance of each process unit.
- Verification of the hydraulic loading on each process.
- Laboratory jar testing to determine the best combination of treatment chemicals and the optimum dosages to achieve maximum removal of particulates and dissolved organic material, as well as a minimum level of aluminum residual in the treated water.
- Make required changes to plant operation at full-scale to ensure that changes will minimize the formation of THMs, but will not compromise the disinfection requirement.

2.0 OBJECTIVES

The two main objectives of the study are:

1. IMPROVEMENT OF THE WARKWORTH WATER TREATMENT PLANT PERFORMANCE

- Improve plant performance without major capital/equipment expenditures. Specific water quality objectives are listed below in decreasing order of priority:

  i To comply with the 100 μg/L ODWO for THMs in treated water as a running annual average of 4 quarterly samples. This objective shall be met while ensuring proper removal and/or inactivation of disease-causing microorganisms such as bacteria and viruses, since this remains the most critical aspect of drinking water treatment.

  ii To improve particulate removal to reduce or eliminate disease risk from giardia and cryptosporidium. While the ODWO for turbidity is 1.0 NTU, the goal is to achieve 0.1 NTU in the filter effluent.

  iii To keep aluminum residual at or below 100 μg/L to meet the ODWO.

2. SUSTAINING LONG-TERM PERFORMANCE

- Skills transfer to plant operating staff to enable them to effectively control and adjust processes over the long term in response to raw water quality variations.
- Documentation of plant conditions with recommendations for up-grades and operational modifications.

3.0 DOCUMENTATION OF EXISTING CONDITIONS

The Township of Percy is the owner of the water treatment plant and distribution system serving the Police Village of Warkworth. The plant is operated by the Township. Warkworth is located at the intersection of Northumberland County Roads 25 and 28 west of Highway 30. The previous water supply and treatment system was constructed and commissioned in the late 1960's. The new facility was commissioned in late 1992. The current water treatment plant and distribution system was designed to service an equivalent population of 987 with at design capacity of 1,232 m^3/d. The current Village population is approximately 650. Water supply to the Police Village of Warkworth water plant is taken from Mill Creek. The Creek is a tributary of the Trent River which flows to the Bay of Quinte.

The raw water characteristics are:

Colour:	5 to 100 TCU
Turbidity:	1 to 5 NTU
pH:	7.8 to 8.3
Alkalinity:	200 to 220 mg/L (as $CaCO_3$)

Plant flows are generally:	Average day	308 m^3/d
	Maximum daily flow	488 m^3/d
	Plant Rated capacity	1,232 m^3/d

The water treatment plant at the beginning of the optimization study consisted of:

- Low lift pumping drawing raw water from Mill Creek.
- Coagulant feed systems for PACl and polymer.
- In-line static mixer.
- One (1) Napier-Reid packaged plant including:
  - Three (3) flocculation tanks.
  - One (1) sedimentation tank with tube settlers
  - Two (2) dual media filters.
- One (1) clearwell storage located under the packaged plant and chemical area.
- Chlorine feed system for pre and post disinfection.
- Vertical turbine high lift pumps.

The plant is operated approximately 8 hours per day all year round.

3.1 THE TREATMENT PLANT PROCESS

The original plant was commissioned in 1969 and consisted of direct filtration together with pre and post chlorination, high and low lift pumping, and treated water storage. Construction of the expanded facilities was completed in November 1992. The expanded plant consists of raw water pumping, chemical feed, in-line static mixer and a Napier-Reid packaged plant which includes three flocculation tanks, one sedimentation tank with tube settlers, and two dual media gravity filters. The filter effluent is discharged into a four-celled clearwell interconnected to the high lift pumps. The clearwell is located below the packaged plant and chemical area. The filters are backwashed with a separate pump.

A plant survey was performed during a site visit on May 29 1997, to prepare a detailed description of the existing equipment and the condition of operation. The survey is documented in Appendix A, and the Certificate of Approval in Appendix C. A plant schematic is presented in Figure 3.1.

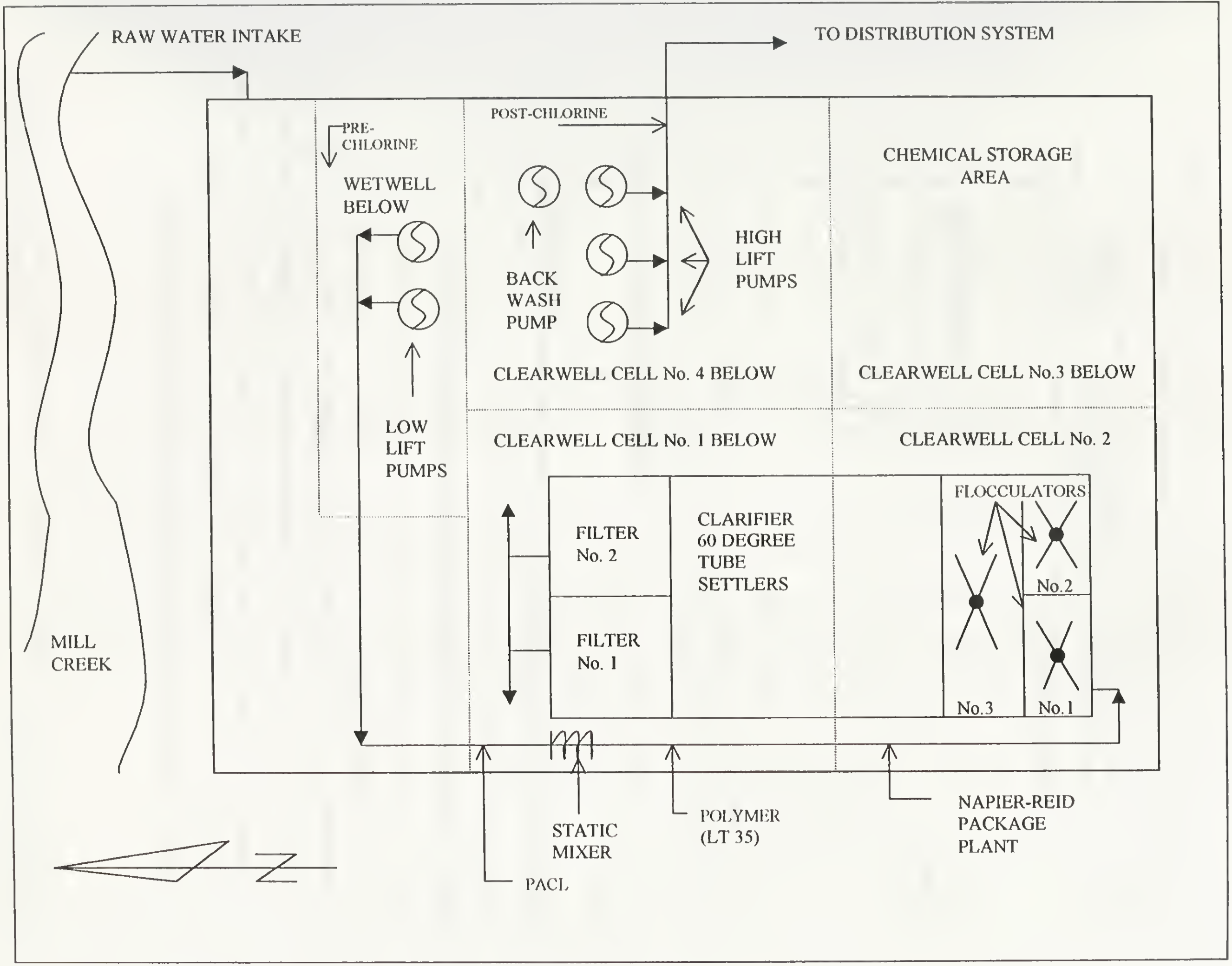


FIGURE 3.1 WARKWORTH WATER TREATMENT PLANT SCHEMATIC

A process unit model for the plant operated at design flow (1,232 m^3/d) is as follows:

MIXING	FLOCCULATOR (3 UNITS)		CLARIFIER WITH TUBE SETTLERS (1 UNIT)		FILTER (2 UNITS)	
	OVERALL DIMENSIONS					
	L	4.09 m	L	6.70 m	L	2.50 m
	W	2.44 m	W	2.70 m	W	1.35 m
	D	2.44 m	D	2.44 m	D	2.44 m
STATIC MIXER	VOL	24.4 m^3	AREA	18.09 m^2	AREA	3.4 m^2
			VOL	44.1 m^3	VOL	8.2 m^3
	MIXERS	0.19 kW	RATE	2.84 m/h	RATE	7.60 m/h
	G floc 1&2	6.85 s^{-1}	TIME	52 min		
	Gt floc 1&2	1,941				
	G floc 3	3.40 s^{-1}				
	Gt floc 3	3,875				
	TOT. TIME	28 min				

MOE GUIDELINE

1000 s-1	Gt	50,000	Min.	3.8	m/h	Recom.	9	m/h
	to	125,000	to	5.8	m/h	Max.	12	m/h

A description of the process unit operations associated with the plant is as follows:

3.1.1 Intake Structure

An existing dam provides the necessary impoundment to the creek to provide water to the plant through the intake system. The dam is constructed using stop logs and is located in close proximity to the plant at the north end of the site. Raising and lowering of the stop logs controls the water flow to the plant. The intake pipe consists of a 250 mm diameter cast iron pipe, 25 m long and extending from the intake manhole into the low lift wetwell.

Screening is used to prevent objects from entering the low lift pumping station and subsequently causing damage to the pumps. A manual bar screen is positioned on the inlet and a fine stationary screen with 6 mm openings is located on the outlet of the manhole. Spacing between the manually cleaned bar screen is 75 mm. The manhole is connected to the intake feeding the low lift pumps.

3.1.2 Low Lift Pumping

The low lift pumps pump raw water from the wetwell to the treatment unit. The low lift pumping station is equipped with two (2) submersible pumps. Each pump is capable of meeting the design flow and has a capacity of 14.3 L/s and a total dynamic head of 7.8 m.

The duty low lift pump operates in response to a lowering of the level in the clearwell. The electric starter for the duty pump is energized and water is pumped from the wetwell to the inlet of the package plant. The pump operates at a constant rate until the water level in the reservoir comes up to top water level.

3.1.3 Static Mixing

The Koflo in-line mixer is constructed of 316 stainless steel, and is 150 mm diameter and 752 mm long. The mixer is located in line between the low lift pumps and the flocculation chambers. PACl is added upstream of the mixer, and the polymer is added after the mixer. Coagulants react (hydrolyze) in water very quickly. In order to be effective the chemical must be mixed rapidly and thoroughly to come in contact with all of the raw water during this critical stage. The effectiveness of the process is determined by visual observation of floc formation within the treatment flocculation zone.

3.1.4 Flocculation

After the static mixer, the coagulant water is allowed to flocculate in a series of flocculation tanks. The package plant has three flocculation tanks arranged in series, each equipped with vertical paddle-type mixers. Mixer speed is pre-set in the first two tanks and the control is on/off. The mixer in the final tank has variable-speed control which can be manually set at different speeds to optimize the process. The first two tanks are equal in size and the final tank is equal in size to the first two combined. Water enters the first tank at the top tangential to the mixer direction. Water exits the first tank and enters the second tank along the bottom of a common wall that divides them. Water exits the second tank and enters the final tank through a rectangular opening in the corner of the tank approximately halfway between the top and bottom of the tank. Water exits the final tank through two circular orifices that lead to the bottom of the settling tank. The energy gradient (Gt) factors for the three flocculation tanks at design capacity (1,232 m^3/d) are well below the level recommended by the MOE Guideline (MOE, April 1982), reducing potential for floc shearing.

3.1.5 Sedimentation

The package plant was supplied with one clarifier including a layer of plastic tube settlers inclined at a 60 degree angle to the horizontal. Sludge accumulated in the tubes settles out by gravity and collects in the sludge bed in the bottom of the clarifier. The overall dimensions of the clarifier are 6.7 m x 2.7 m x 2.44 m deep. The rise rate for the plant rated capacity is 2.84 m/h. The MOE guideline for this type of clarifier is 3.8 to 5.8 m/h.

3.1.6 Filtration

A two compartment gravity dual media filter is part of the plant. The two filters are operated in parallel at a filtration rate of 7.6 m/h at plant rated capacity. This is below the MOE recommended rate of 9 m/h for a plant of this size and type. The overall surface area for the two filters is 3.4 m^2 (2.5 m x 1.35 m) per filter. Effluent from the filters is discharged to the clearwell located below the filter and chemical area.

There is a separate backwash pump drawing water from the clearwell. The backwash pump is a single vertical turbine with a capacity of 47 L/s at a total dynamic head of 15 m.

3.1.7 Clearwell and Reservoir

A 480 m^3 in-ground treated water clearwell is located under the packaged plant and chemical area. The clearwell consist of four (4) cells with valved interconnections. An in-ground reservoir with an approximate volume of 506 m^3 is located in town to provide additional storage required for peak hour, fire and emergency storage needs.

3.1.8 High Lift Pumping

Water from the reservoir is pumped to the distribution system by three high lift vertical turbine pumps, each rated at 10.8 L/s with a total dynamic head of 46 m.

3.1.9 Wastewater Disposal

There are two backwash wastewater holding tanks with a capacity of 24.6 m^3 each. The two tanks are capable of holding the contents of one filter backwash and one sludge blowdown. Flow can be directed to either tank on alternating days. When the level reaches a certain level, an ultra sonic sensor activates submersible wastewater transfer pumps located in each tank to pump to the settling tank. Transfer is done in batches to allow the sludge to settle in the settling tank and supernatant to be transferred in between pumping. The supernatant is discharged to the creek, and the accumlated sludge is collected by truck and discharged to the municipal lagoon.

3.2 CHEMICAL FEED SYSTEMS

The chemical feed systems used at the plant at the beginning of the study are summarized as follows:

Process Function	*Chemical*	*Locations Added*
Primary coagulant	PACl	In-line static mixer on the raw water line.
Coagulant aid	LT35 polymer	Low lift header after the in-line mixer.
Disinfection	Sodium Hypochlorite	Pre: In the wetwell. Post: High lift pumps header.

3.2.1 PACl

Polyaluminum chloride (PACl) is stored in a 15 m^3 fibreglass tank. The storage tank contains 219 days of coagulant supply at maximum day demand. PACL is transferred to a 454 L day tank. Two diaphragm metering pumps (one duty and one standby) dose the coagulant. The chemical is transferred via a feed line installed in the low lift pump discharge pipe up-stream of the in-line static mixer. The dosage applied is approximately 20 mg/L all year around, but is capable of 60 mg/L at 14.3 L/s flowrate.

3.2.2 Polymer Feed

The coagulant aid used at the plant is Percol LT35 in a liquid form. The dosage is approximately 0.5 mg/L. The polymer solution is fed into the low lift pumps header, between the in-line mixer and the first flocculation tank. This has not been used for over a year because the operator reports that LT35 addition has no effect.

3.2.3 Disinfection

At the beginning of the study, a 12 % nominal strength sodium hypochlorite solution was added to the raw water via a diffuser located at the inlet to the low lift wetwell. The applied dosage ranged from 1.5 to 2.1 mg/L. Two chemical feed pumps (one duty and one standby) were used for dosing. Each pump was capable of delivering a maximum of 3.8 L/h at 760 kPa, which would result in a maximum dosage of 7.4 mg/L at plant capacity. The pump operation was controlled by the operation of the low lift pumps. Dosage rate was controlled by manually adjusting the stroke length.

Post-chlorine disinfection was done at the high lift pump header with two dosing pumps (one duty, one standby). Each pump is capable of delivering a maximum of 3.8 L/h at 760 kPa, which would equate to a maximum dosage of 4.9 mg/L at maximum pumping rate. Pacing for the pumps was provided through a 4-20 mA control loop from the treated water flow meter. The applied dosage varied from 1.4 to 2.3 mg/L. The pre and post chlorine dosing pumps were operated to maintain a free chlorine residual in the treated water leaving the plant of approximately 1.0 mg/L.

3.3 FLOW MEASUREMENT

The operation of the high lift pumps is controlled by the level of the in-ground reservoir located in Town. The treated water flow rate is measured by a magnetic type flow meter on the high lift discharge and recorded on a chart recorder. Raw water flow is also measured with a magnetic type meter.

3.4 HISTORICAL DATA

Historical data from January to December 1996 for turbidity, colour, pH, alkalinity, THMs, dissolved organic carbon (DOC) and aluminum residual found in the raw and the treated water are presented in Table 3.1. The water samples were analyzed by the Ministry of the Environment Central Laboratory.

A summary is presented below:

Parameters	*Units*	*Range*	*Average*
Turbidity - Raw Water:	NTU	0.8 to 5.8	2.1
Turbidity - Treated Water:	NTU	0.1 to 0.9	0.4
Colour - Raw Water:	TCU	9 to 39	23
Colour - Treated Water:	TCU	2 to 11	5
DOC - Raw Water:	mg/L	0.5 to 7.5	5.0
DOC - Treated Water:	mg/L	2.0 to 6.2	3.9
pH - Raw Water:		7.6 to 8.5	8.0
pH - Treated Water:		7.3 to 8.4	7.9
Alkalinity - Raw Water:	mg/L-$CaCO_3$	180 to 227	208
Alkalinity - Treated Water:	mg/L-$CaCO_3$	164 to 212	197
Aluminum - Raw Water:	µg/L	10 to 14	12
Aluminum - Treated Water:	µg/L	10 to1,900	476
THMs - Treated Water:	µg/L	77 to 194	148
THMs - Distribution System:	µg/L	82 to 158	121

The variation in colour for the raw and the treated water is presented in Figure 3.2. Historical data for 1996 indicated a raw water colour ranging from 9 to 39 TCU with a peak value measured in October. The colour in the treated water varied from 2 to 11 TCU for an average of 5 TCU. The monthly average colour exceeded the Ontario Drinking Water Objective (ODWO) of 5 TCU for a total of three months in 1996. Colour is referred as an aesthetic parameter but remains of importance since it is often indicative of high levels of organics in the raw water which can lead to high THMs formation.

The average concentration of dissolved organic carbon (DOC) in the raw water was 5 mg/L. DOC levels in the treated water varied from 2.0 to 6.2 mg/L for an average of 3.9 mg/L. This is below the ODWO of 5 mg/L. High levels of colour and DOC in the raw and treated water present a higher potential for THMs formation since organics in the water will react with free chlorine to form THMs.

High levels of THMs were observed in July, September and October of 1996. The average THMs values for that year in the treated water and the distribution system were 148 and 121 µg/L respectively, which is in excess to the new ODWO guideline of 100 µg/L.

The variation of turbidity for the Warkworth treatment plant is presented in Figure 3.3. The raw water turbidity was variable and ranged from 0.8 to 5.8 NTU with peak values measured in August and November (3.0 and 5.8 NTU respectively). The turbidity in the treated water ranged from 0.1 to 0.9 NTU for an average of 0.4 NTU. The effluent turbidity is below the ODWO of 1.0 NTU, but remains above the objective for this study of 0.1 NTU for protection against cryptosporidium and giardia.

The pH of the raw water is relatively high and varied from 7.6 to 8.5 for an average of 8.0. There is no pH adjustment performed on the raw water therefore the pH of the treated water remains almost the same with an average pH of 7.9.

The aluminum residual in the raw water was low and generally below 14 µg/L. The aluminum residual in the treated water was widely variable and ranged from 10 to 1,900 µg/L. The highest values were measured in January and February. The ODWO for aluminum in the treated water is 100 µg/L. This guideline is not health related but is an operational guideline set to reduce post precipitation of alum in the distribution system.

TABLE 3.1 WARKWORTH WATER TREATMENT PLANT
MONTHLY AVERAGE WATER QUALITY RESULTS FOR 1996
WATER SAMPLES ANALYZED BY THE MOE, CENTRAL LABORATORY

	Jan-96	Feb-96	Mar-96	Apr-96	May-96	Jun-96	Jul-96	Aug-96	Sep-96	Oct-96	Nov-96	Dec-96	AVERAGE
ALUMINUM - RAW WATER (ug/L)	14	13	-	-	10	-	-	-	10	-	-	-	12
ALUMINUM - TREATED WATER (ug/L)	1200	1900	10	40	-	-	-	10	90	-	80	-	476
COLOUR - RAW WATER (TCU)	25	9	13	17	-	-	29	34	-	39	21	23	23
COLOUR - TREATED WATER (TCU)	5	2	3	2	-	-	9	7	-	11	3	2	5
DOC - RAW WATER (mg/L)	2.9	2.8	7.4	5.7	-	-	5.5	0.5	7.5	-	5.5	6.8	5.0
DOC - TREATED WATER (mg/L)	2.1	2.0	5.8	4.4	-	-	4.6	0.5	6.2	-	5.2	4.7	3.9
pH - RAW WATER	8.2	8.2	8.0	7.6	-	-	8.5	7.9	-	-	8.0	8.0	8.0
pH - TREATED WATER	8.0	8.0	7.7	7.3	-	-	8.4	7.8	-	-	7.9	7.9	7.9
ALKALINITY - RAW WATER (mg/L-$CaCO_3$)	217	218	202	180	200	-	227	222	214	206	214	192	208
ALKALINITY - TREA. WATER (mg/L-$CaCO_3$)	205	203	200	164	184	-	212	200	192	-	208	204	197
TEMPERATURE - RAW WATER (°C)	2	-	3	6	11	17	19	19	14	9	4	2	10
TEMPERATURE -TREATED SYSTEM (°C)	5	-	6	8	12	18	19	19	16	10	5	6	11
TURBIDITY - RAW WATER (NTU)	0.9	1.6	1.5	1.8	-	-	2.3	3.0	-	1.6	0.8	5.8	2.1
TURBIDITY - TREATED WATER (NTU)	0.5	0.5	0.2	0.2	-	-	0.1	0.3	-	0.9	0.6	0.5	0.4
THMs - TREATED WATER (ug/L)	-	77	-	-	-	-	148	-	194	171	-	-	148
THMs - DISTRIBUTION SYSTEM (ug/L)	-	82	-	-	-	-	97	-	158	145	-	-	121

NOTES:

THMs RESULTS FOR TREATED WATER AND DISTRIBUTION SYSTEM IN AUGUST 1995 WERE 134 AND 51 ug/L.
THMs RESULT FOR TREATED WATER AND DISTRIBUTION SYSTEM IN NOVEMBER 1995 WAS 88 ug/L.

FIGURE 3.2 COLOUR FOR WARKWORTH WTP

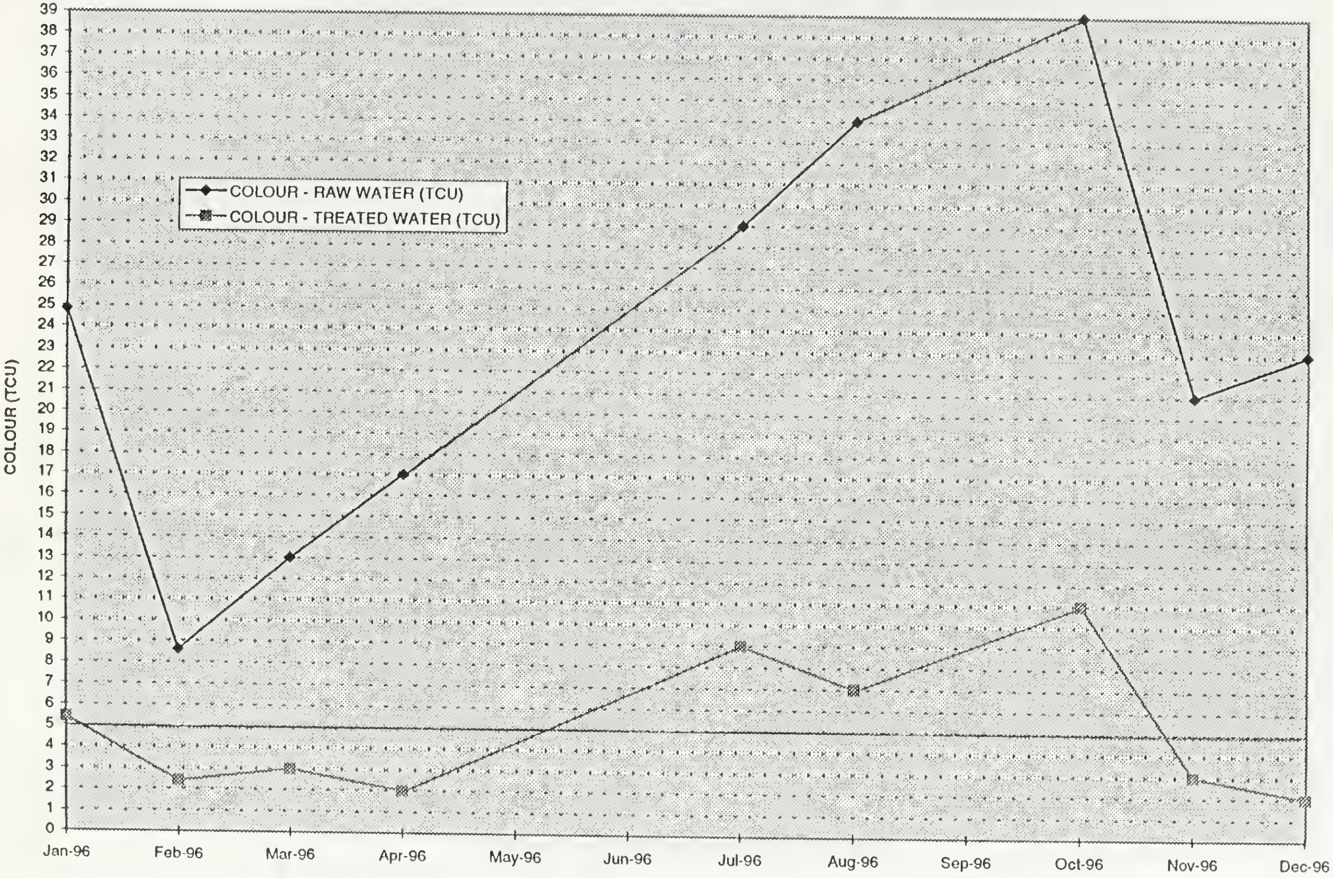
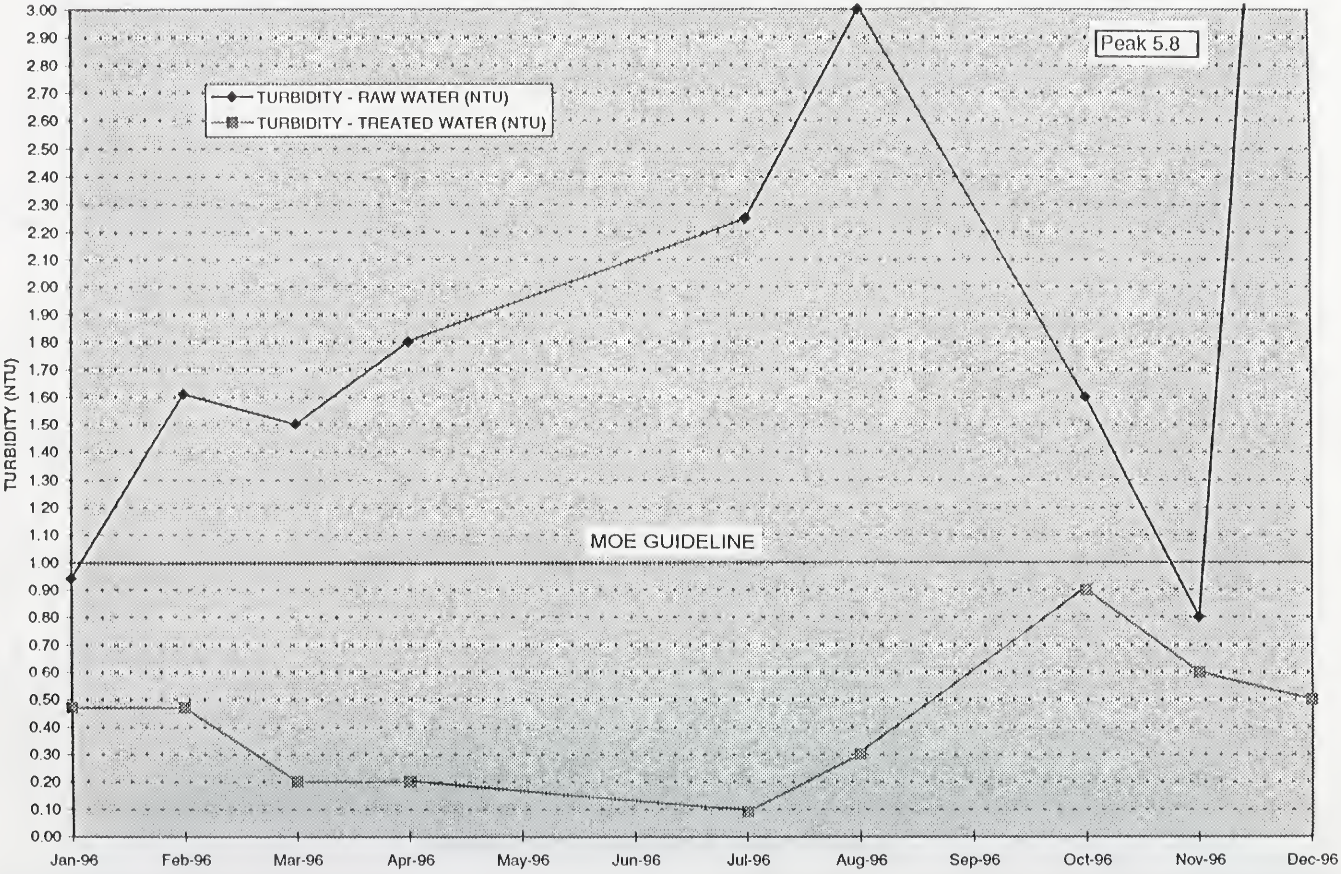


FIGURE 3.3 TURBIDITY WARKWORTH WTP



4.0 PERFORMANCE ASSESSMENT

4.1 1997 WATER SAMPLING

Water samples were collected at the treatment plant in July and August 1997 to establish a baseline for THMs versus the level of colour and total organic carbon (TOC). Maxxam Analytics Inc. analyzed the samples. The results obtained from 6 weeks of sampling are summarized in Table 4.1. The operation data collected at the plant for the days of sampling including average daily flow, turbidity, raw water temperature and chemical dosages are presented in Table 4.2.

The critical parameters exceeding the objectives of this optimization study during the 1997 water sampling are summarized as follows:

- The average pH of the raw water is 8.2, which is high and would contribute to the high aluminum residual in the treated water.
- The raw water turbidity measured at the plant (Table 4.2) varied from 1.8 to 2.5 NTU. The average treated water turbidity ranged from 0.2 to 0.7 NTU for an average of 0.4 NTU. The turbidity did not exceed the ODWO of 1 NTU but exceeded the operational objective of this study of 0.1 NTU. An option available to improve particulate removal is to optimize the coagulant and coagulant aid dosage through jar testing, and possibly adjustment of the pH of the raw water.
- The THMs measured in the treated water at the plant varied from 56 to 170 µg/L, for an average of 116 µg/L. The THMs levels in the distribution system varied from 52 to 230 µg/L, for an average of 125 µg/L. The THMs during the summer of 1997 exceeded the new ODWO of 100 µg/L. An option available to reduce the formation of THMs is to stop pre-chlorination of the raw water and post-chlorinate the treated water leaving the filter.

The water samples taken in the distribution system for THMs analysis were quenched with sodium thiosulfate to remove any chlorine residual to stop further reaction between free chlorine and organics. Quenched water samples will maintain the same level of THMs as existed at the time of sampling representing the quality experienced by the consumer. The water samples taken at the water treatment plant for THMs analysis were not quenched, the reason being to simulate the effect of additional contact time in the distribution system versus the development of THMs.

Based on THMs, colour and TOC analysis performed for the Warkworth Water Treatment Plant, there is some evidence of a relation between the level of colour or TOC in the water and the level of THMs formed. The highest THMs level was measured at a time when TOC was the highest as would be expected. The weak THMs-colour correlation may be attributed to the limited number of samples collected, and the variable level of chlorine residual. Other factors which may have contributed to the poor correlation include the relatively narrow range of colour value observed, and the analytical variability for THMs analysis. The detection limit of the analytical procedures and the method reference used by Maxxam Analytics is summarized in Appendix D.

Additional analysis were performed to evaluate the level of haloacetic acids (HAAs) in the treated water. HAAs are by-products of disinfection with chlorine reacting with humic substances. HAAs may be of concern to human health. Currently, there is no guideline in Ontario regulating the maximum level of HAAs in drinking water. The US Environmental Protection Agency (USEPA) has proposed regulating five major HAAs in the upcoming Disinfectants/Disinfection By-products (D/DBP) Rule – monochloroacetic acid (MCAA), DCAA, TCAA, monobromoacetic acid (MBAA), and dibromoacetic acid (DBAA). In the first stage of the D/DBP Rule, the proposed maximum contaminant level is 60 μg/L for the total concentration of these five HAAs.

Samples were taken in the treated water at the plant and in the distribution system for HAAs analysis. The samples taken at the plant were unquenched and the samples in the distribution system were quenched with ammonium chloride to stop any further formation representing the quality experienced by the consumer. The level of HAAs in the treated water at the plant varied from 114 to 141 µg/L for an average of 130 µg/L. HAAs concentrations in the distribution system varied from 88 to 123 µg/L for an average of 101 µg/L.

TABLE 4.1 JULY AND AUGUST 1997 SAMPLING FOR WARKWORTH WATER TREATMENT PLANT WATER SAMPLES ANALYZED BY MAXXAM ANALYTICS

PARAMETERS	WEEK 1 (97/07/08)	WEEK 2 (97/07/16)	WEEK 3 (97/07/22)	WEEK 4 (97/07/29)	WEEK 5 (97/08/05)	WEEK 6 (97/08/12)	MINIMUM	MAXIMU	AVERAGE
Turbidity - Raw Water (NTU)	5.5	1.7	1.7	1.2	1.6	1.1	1.1	5.5	2.1
Turbidity - Treated Water (NTU)	1.3	0.4	0.8	0.3	0.9	0.6	0.3	1.3	0.7
Colour - Raw Water (TCU)	8	14	12	10	9	11	8	14	11
Colour - Treated Water (TCU)	1	3	2	2	3	1	1	3	2
Colour - Distribution System (TCU)	1	3	1	2	3	1	1	3	2
pH - Raw Water	7.8	8.3	8.2	8.2	8.2	8.2	7.8	8.3	8.2
pH - Treated Water	8.1	8.1	8.0	8.0	8.1	7.9	7.9	8.1	8.0
Alkalinity - Raw Water (mg/L - $CaCO_3$)	209	201	214	209	212	207	201	214	209
Alkalinity - Treated Water (mg/L - $CaCO_3$)	199	181	196	189	189	189	181	199	191
TOC - Raw Water (mg/L)	5.0	3.2	3.1	2.9	2.5	8.7	2.5	8.7	4.2
TOC - Treated Water (mg/L)	4.7	2.5	3.4	2.0	2.2	1.6	1.6	4.7	2.7
TOC - Distribution System (mg/L)	4.7	2.7	2.2	2.1	2.0	1.7	1.7	4.7	2.6
THMs - Unquenched Treated Water (ug/L)	170	140	140	110	81	56	56	170	116
THMs - Quenched Distribution System (ug/L)	230	110	150	110	52	100	52	230	125
HAAs - Unquenched Treated Water (ug/L)	141	135	114	-	-	-	114	141	130
HAAs - Quenched Treated Water (ug/L)	123	88	91	-	-	-	88	123	101

TABLE 4.2 JULY AND AUGUST 1997 SAMPLING FOR WARKWORTH WATER TREATMENT PLANT OPERATION DATA COLLECTED AT THE WTP

PARAMETERS	WEEK 1 (97/07/08)	WEEK 2 (97/07/16)	WEEK 3 (97/07/22)	WEEK 4 (97/07/29)	WEEK 5 (97/08/05)	WEEK 6 (97/08/12)	MINIMUM	MAXIMUM	AVERAGE
Average Daily Flow - Raw Water (m^3/d)	344	407	190	549	523	505	190	549	420
- Treated Water (m^3/d)	258	308	259	401	479	345	258	479	342
Turbidity - Raw Water (NTU)	2.5	1.8	2.5	2.2	2.4	2.5	1.8	2.5	2.3
Turbidity - Treated Water (NTU)	0.3	0.5	0.5	0.5	0.7	0.2	0.2	0.7	0.4
Colour - Raw Water (ACU)	51	44	51	40	56	58	40	58	50
Colour - Treated Water (ACU)	1	4	4	3	4	5	1	5	4
Temperature - Raw Water (^oC)	20	25	19	21	20	20	19	25	21
Free Chlorine Residual (mg/L)	1.1	1.0	0.9	1.7	0.3	0.7	0.3	1.7	1.0
Total Chlorine Residual (mg/L)	N/A	N/A	N/A	N/A	N/A	N/A			
PACL Dosage (mg/L)	18	21	18	21	20	23	18	23	20
Percol LT35 Dosage (mg/L)	1.1	0.8	0.8	0.9	0.8	0.7	0.7	1.1	0.8
Pre-Sodium Hypochlorite Dosage (mg/L)	2.5	2.0	2.1	2.3	1.6	1.2	1.2	2.5	2.0
Post-Sodium Hypochlorite Dosage (mg/L)	2.2	2.1	2.4	2.6	1.8	1.8	1.8	2.6	2.2

NOTE: N/A: Not Available

4.2 PROCESS UNIT ASSESSMENT

The performance evaluation for the different process units is presented below:

4.2.1 Mixing

Chemical mixing is provided by an in-line static mixer installed on the low lift pump header immediately after the polyaluminum chloride (PACl) injection to provide adequate mixing of treatment chemical.

4.2.2 Flocculation

The three flocculation tanks are designed to provide a mixing zone to promote flocculation/coagulation. Polymer (Percol LT35) is added to the low lift pump header after the in-line static mixer and before the tanks. The calculated input energy (Gt factor) for the first and second compartments is 1,633 at maximum daily flow (488 m^3/d) when the plant is operated only 8 hours per day. This represents an equivalent maximum daily flow rate of 1,464 m^3/d (488 m^3/d x 24/8). The first two flocculation tanks are equipped with a constant speed motor. The GT factor for the third flocculator which is provided with a variable speed motor is 3,261 for a total Gt factor in the three tanks of 6,527. This is lower than the minimum GT value recommended by the MOE (50,000).

The most critical factor to promote floc formation at the Warkworth plant is to provide sufficient contact time in the flocculation tanks. At present the floc formed is very small which is a common problem of low turbidity and high colour in the raw water. The total contact time is 28 minutes at design capacity (1232 m^3/d). Since the plant is operated at full rate for approximately 8 hours per day the residence time applies to the existing operation. This will contribute to formation of small difficult to settle floc. A total contact time of 48 minutes could be provided by reducing plant flow rate by one-half.

4.2.3 Clarification

The rise rate in the clarifier at design capacity (1232 m^3/d) is 3.37 m/h which is below the MOE guideline (3.8 to 5.8 m/h). Similar to the discussion regarding flocculation the plant is run at full rate for approximately 8 hours. Even with a low rise rate the unit is not performing very well with frequent pin floc carry over to the filter. A longer residence time and lower rise rate would help to settle the floc.

4.2.4 Filtration

The filtration rate of the two filters is 9.04 m/h when the plant is operated at design capacity (1232 m^3/d) for only 8 hours per day. This is conservative compared to the MOE guideline (9 to 12 m/h), indicating that the filters should be capable of efficient turbidity removal. The filtration process would be greatly improved by improving solids settling in the clarifiers to reduce floc carry over. A stronger and bigger floc can be developed by optimizing chemical dosage and coagulant aid selection.

4.2.5 Disinfection

Disinfection of drinking water is the most important aspect of the treatment process. Harmful organisms in water such as bacteria, viruses or cysts can cause illness ranging from minor intestinal disorders to potentially fatal infections. Maintaining an effective disinfection system must be the overriding priority of the plant operations. For surface waters, chlorination with a 'free' residual is the most common and most practical method of disinfection. To be effective, the treated water must be very low in turbidity as suspended particles can shield bacteria and viruses from the effects of chlorine. Turbidity levels greater than 0.1 NTU indicate an increased probability of chlorine resistant cysts being present.

To achieve a safe level of disinfection, it is necessary to dose the treated water with a sufficient amount of chlorine to produce a 'free' residual, and to give the chlorine sufficient time to inactivate the potentially harmful organisms. This is called the concentration-time factor or CT, also referred to as the primary disinfection stage.

Sufficient CT must be achieved at the treatment plant before the first service connection. Current MOE guidelines call for a minimum residual of 0.5 mg/L for a minimum contact time of 30 minutes after filtration. This disinfection guideline for water treatment plants in Ontario is under review, and the new guideline may be similar to the Surface Water Treatment Rule (SWTR) promulgated by U.S. Environmental Protection Agency (U.S. EPA). The SWTR established CT values for chlorine, chlorine dioxide, ozone and chloramines required to achieve adequate inactivation of giardia cysts and viruses. For the purpose of calculating CT value, T is the time (in minutes) it takes the water, during peak plant flows, to move between the point of disinfectant application and a point where, C, residual disinfectant (in mg/L) concentration is measured just prior to the first customer. The calculation must account for the degree of short circuiting in the storage tank.

For free residual chlorination, the CT required is based on the inactivation of giardia cysts in cold water. Giardia cysts are harder to inactivate by free chlorine than viruses, therefore, it is implied that proper inactivation of giardia cysts will ensure inactivation of viruses. Disinfection with chlorine is not effective for the inactivation of cryptosporidium. Therefore, it is necessary to perform adequate filtration at the water treatment plant for any municipality at risk of cryptosporidium outbreaks.

Secondary disinfection refers to the maintenance of a residual in the distribution system to protect against bacterial re-growth or minor cross connection contamination. This maintenance residual is commonly achieved with 'free' chlorine, but alternatively can be converted to chloramine or 'combined' residual with the addition of ammonia. Chloramines have the advantage of being more stable and lasting much longer in the system. They also do not react with organics to form THMs. They are however much less effective as a disinfectant and are very weak in inactivating viruses and cysts. Use of chloramine as a primary disinfectant is therefore not recommended.

The MOE guidelines recommend a minimum free chlorine residual of 0.2 mg/L at the end of the distribution system. The AWWA recommends a residual of 1.0 mg/L of chloramine be maintained to prevent re-growth (AWWA, 1993). These chlorine residuals do not take into consideration water characteristics such as temperature and pH that affect disinfection efficiency.

According to the SWTR, all community and non-community public water systems which use a surface water source or a ground water under the direct influence of a surface water must achieve a minimum of 99.9 percent (3-log) removal and/or inactivation of giardia cysts. According to these guidelines, systems with sewage and agricultural discharges to the source water should provide treatment to achieve an overall 99.999 percent (5-log) removal/inactivation of giardia cysts, while the minimum required 3-log removal/inactivation is sufficient for sources with no significant microbiological contamination from human activities, a 4-log removal/inactivation of cysts should be provided for source waters whose level of microbiological contamination is between these two extremes.

There is agricultural activity along the Mill Creek, but it is reported there is no significant microbiological contamination from human activities. Therefore, a 4-log removal/inactivation of cysts is considered appropriate. Well-operated conventional treatment plants which have been optimized for turbidity removal can be expected to achieve at least a 2.5-log removal of giardia cysts. The minimum turbidity performance criteria for systems using conventional treatment is that the filtered water turbidity must be less than or equal to 0.5 NTU in 95 percent of the measurements taken every month. Results collected in 1996 and 1997 show that the filtered water turbidity exceeds 0.5 NTU at times. Some modifications to the filter performance should be implemented to improve the overall performance of the filter operation. This procedure is explained in detail in Section 8.0. The required CT will be based on 1.5-log inactivation of giardia cysts (4.0 total - 2.5 log credit for filtration).

Examples of CT calculations for different water temperatures when the plant is operated at rated capacity (1,232 m^3/d) are presented in Appendix E.

Based on the "Guidance Manual for Compliance With the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Source" (U.S. EPA, 1990), the baffle condition in the clearwell expressed as T_{10}/T factor can be evaluated to estimate the effective contact time in the clearwell. This factor represents the ratio between T_{10}, which is the time it takes 10 percent of a dye or tracer to pass through the basin outlet after it is injected into the basin influent flow, and the theoretical detention time for plug flow in pipelines and flow in a completely mix chamber. When tracer studies are not available, a description of the clearwell and baffling condition can be used to estimate the T_{10}/T factor.

A baffling factor T_{10}/T of 0.5 was used for the calculations representing an average baffle condition when a clearwell includes some intra-basin baffles. The clearwell at the Warkworth Water Treatment Plant is divided into four cells. The pH of the raw water used for the calculations was 8.0 and remains relatively constant through the year. The CT calculations were done under the most critical condition when the clearwell is 70% full. The control system automatically turns the low lift pump on, when the water level in the clearwell is one metre below the maximum water level, which represent 70% of the capacity of the clearwell. This should reflect the situation at the water treatment plant where the package treatment unit is producing the plant rated capacity (1,232 m^3/d), and the high lift pumps are pumping at peak hourly rate to the distribution system. The estimated contact time in the clearwell under these conditions is estimated to be 196 minutes.

TABLE 4.3 Minimum residual free chlorine concentration required at the clearwell outlet for inactivation of giardia cysts

CONDITIONS	**Free Residual Chlorine Concentration (mg/L) C**
• Temperature of the raw water: 0.5 °C	0.74
• Temperature of the raw water: 5 °C	0.51
• Temperature of the raw water: 10 °C	0.38
• Temperature of the raw water: 15 °C	0.25
• Temperature of the raw water: 20 °C	0.19

The results presented in Table 4.3 show that a higher chlorine residual is required during the winter since lower water temperature reduces the rate of inactivation. The free chlorine concentration required during the winter condition, when the water temperature is around 0.5 °C is 0.74 mg/L. The minimum free chlorine concentration required during the summer for a water temperature of 20 °C is 0.19 mg/L. The free chlorine residual must be measured at the clearwell outlet (i.e. from cell #4 in clearwell). The free chlorine residual leaving the plant was maintained to approximately 1 mg/L during the summer of 1997 by the existing post-clearwell feed. The operator should adjust the chlorine feed rate of the proposed filter effluent feed point to try to achieve the required free chlorine residual in the clearwell as summarized in Table 4.3. The operator should always ensure that enough chlorine is added at the existing post-clearwell feed point to maintain a free chlorine residual of 0.2 to 0.3 mg/L at the end of the distribution system.

5.0 OFF-SITE BENCH SCALE EVALUATIONS

5.1 INTRODUCTION

Jar testing was conducted by the MOE Standards Development Branch in September 1997. The primary objective of this study was to determine the best treatment chemicals to improve the performance of the Warkworth Water Treatment Plant in terms of colour and turbidity removal. The treatability study was conducted using a conventional mode of treatment consisting of coagulation, flocculation, sedimentation and filtration, as per the plant's mode of treatment. All jar testing was performed at approximately 15°C.

The raw water pH at Warkworth is quite high (8 and over) and the water is relatively coloured with usually low turbidity, making coagulation and production of good floc difficult, especially in winter. The treatability study was conducted to answer the following questions:

- What is the performance of the coagulant currently used, polyaluminum chloride (PACl), and how does it compare to acidified alum?

- What are the best polymers to use with these coagulants to develop a stronger, easier to settle floc?

- How do these coagulants affect final pH? Would pre-adjustment of pH be beneficial?

5.2 JAR TEST SERIES No. 1

Water for the first series of tests was collected on September 22, 1997 from the stream impoundment that supplies the Warkworth plant. Water quality was as follows:

Warkworth Jar Test - Series No. 1
Raw Water Quality

Parameters	Value
Temperature	12 °C
Alkalinity	220 mg/L
pH	8.2
Turbidity	1.5 NTU
True Colour	30 TCU
DOC	5.4 mg/L

This raw water quality is considered "typical" for the Warkworth plant when runoff from storms is not affecting the Mill Creek. The following tables are summaries of all the jar test runs that were done. The actual data sheets are presented in Appendix B.

Run No.1

This run intended to find the optimum dosage of PACl while using Percol LT35 polymer (the polymer used at the plant). Six jars were run at PACl dosages from 20 to 45 mg/L. The plant was dosing at 35 mg/L. LT35 dosages were held constant at 0.5 mg/L. The floc in all six jars was very poor and the runs abandoned.

Run No. 2

It was believed that the poor results in all six jars in run No.1 were likely due to the use of LT35. Therefore, six different polymers (LT20, 22, 24,25, 26, 27A) were tested at 0.5 mg/L together with 35 mg/L of PACl. All six jars produced a floc that was much better than the floc produced by LT35. The best floc was obtained with LT27A (a very viscous polymer). Polymer LT20 and 24 also produced good floc. The aluminum residuals in the six jars were all well over 100 µg/L. This indicates that the optimum PACl dose was higher than 35 mg/L or that the pH was too high for complete coagulation.

Run No. 3

In this run, LT 27A at 0.5 mg/L was tested and compared with LT35 at 1.25 mg/L to confirm the effectiveness of LT27A, and to see if using LT35 at a higher dosage would improve the floc quality. The LT27A again produced excellent floc while the LT35 produced very poor floc. From this point on all runs used LT27A as the coagulant aid. The next step was to find what the optimum PACl dosage was based on supernatant colour and turbidity levels, and based on the aluminum residual of filtrate.

Runs No. 4, No.5 and No.6

A total of 18 jars were run with PACl dosages ranging from 20 to 80 mg/L. LT27A was added to all jars at a dosage of 0.5 mg/L. In general, as PACl dosages increased the supernatant colour and turbidity as well as the filtrate aluminum residuals decreased. A minimum aluminum residual concentration less than 100 µg/L was reached at a dosage of 70 mg/L.

In the next two runs acidified alum manufactured by Alcan was tested to see if the lower pH produced by this chemical resulted in improved quality at lower dosages.

Run No. 7

Six jars were run with Alcan A5 acidified alum ranging from 50 to 100 mg/L. LT27A was added to all jars at a dosage of 0.5 mg/L. The aluminum residual seemed to reach its minimum concentration with 66 µg/L at an A5 dosage of approximately 90 mg/L. The final pH at this dosage was 7.60 compared to 7.88 for the optimum PACl dosage. The turbidity and colour removal in supernatant was not as good as that with PACl.

Run No. 8

Six jars were run with Alcan A7 acidified alum ranging from 50 to 100 mg/L. LT27A was added to all jars at a dosage of 0.5 mg/L. The optimum A7 dosage appeared to be around 90 mg/L. The final pH at this dosage was 7.58 compared to 7.60 for A5 and 7.88 for the optimum PACl dosage. The turbidity removal in supernatant was not as good as that with PACl.

Conclusions from Series No. 1

- The Warkworth plant should abandon the use of LT 35 for use as a coagulant aid.
- For this "typical" Warkworth raw water quality, the optimum PACl dosage was found to be 70 mg/L.
- The best polymer used with PACl was Percol LT27A; LT20 and LT24 are other good choices.
- Limited testing indicated that there were no significant benefits in switching to acidified alum based on dosages required and final treated water quality.

5.3 JAR TEST SERIES No. 2

Water for the second series of tests was collected on September 29, 1997 from the stream impoundment that supplies the Warkworth plant. Raw water quality was as follows:

Warkworth Jar Test – Series No. 2
Raw Water Quality

Parameters	Value
Temperature	14 °C
Alkalinity	196 mg/L
pH	8.0
Turbidity	10.5 NTU
True Colour	47 TCU
DOC	8.3 mg/L

This raw water quality represents the situation at the Warkworth plant when runoff is affecting the Mill Creek. The following are summaries of all the jar test runs that were done. The actual data sheets are presented in Appendix B.

Run No. 1

This run was intended to find the optimum dosage of PACl while using LT27A at 0.5 mg/L in all jars. The PACl dosages ranged from 60 to 110 mg/L. A minimum aluminum residual concentration was not reached, although all jars were less than 100 µg/L. Based on supernatant turbidity and colour, the optimum dosage appeared to be around 90 mg/L.

Run No. 2

This run was intended to find the optimum dosage of A7 acidified alum while dosing LT27A at 0.5 mg/L in all jars. The A7 dosages ranged from 70 to 120 mg/L. A minimum aluminum residual may have been reached at a dosage of 100 mg/L, but it was difficult to evaluate if this result was based on other factors such as supernatant turbidity and colour. An observation was made showing that floc quality was a little better at dosages less than 100 mg/L.

Run No. 3

Both PACl and A7 were tested again for a final evaluation of their optimum dosages. Three jars received PACl at dosages of 50, 90, and 120 mg/L. The other three jars received A7 at dosages of 60, 100, and 140 mg/L. All jars were tested with LT27A at 0.5 mg/L.

Based on supernatant colour and turbidity, the best PACl dosage was 90 mg/L. It should be noted that a minimum concentration was never reached for aluminum residual in the filtered water. It seems that with PACl the minimum will only be reached at very high dosages that bring the pH down to a range of 7.0 to 7.5. However, a higher dosage of PACl is not required since the levels of turbidity, colour and aluminum residuals are all acceptable. At 90 mg/L in runs No.1 and No.3, the final pH was 7.68 and 7.64 respectively, and aluminum residuals were 68 and 63 µg/L respectively. The supernatant turbidities were less than 0.2 NTU and colours were in the 6 to 8 TCU range.

Based on supernatant colour and turbidity, and filtrate aluminum residual in runs No.2 and No.3, it was not possible to conclusively select an optimum dosage for A7. The best estimate would be an optimum dosage of 110 mg/L. At this dosage, aluminum residual would be approximately 80 µg/L and final pH would be 7.2. The colour and turbidity in supernatant was approximately 10 TCU and 0.35 NTU respectively, not as good as PACl. Once again, it was observed that with both A7 and PACl, the floc quality was better at dosages lower than that required for best colour, turbidity and aluminum residual.

Run No. 4

This run was to determine the optimum A10 acidified alum dosage. Six jars were run at dosages ranging from 50 to 150 mg/L. All six jars received LT27A at 0.5 mg/L. The optimum dosage based on supernatant turbidity (0.28 NTU) and colour (8 ACU), and filtrate Aluminum residual (0.076 mg/L) was 110 mg/L. At this dosage the final pH was 7.07. Again, it was interesting to note that the best floc quality was in jars where A10 was underdosed.

Run No. 5

In this run PACl was added at dosages ranging from 50 to 150 mg/L. The objective was to see if a minimum aluminum residual could be reached to confirm if 90 mg/L is the optimum dosage. A minimum aluminum residual was not reached. Each jar progressively had a lower residual ranging from 134 µg/L in the first jar to 36 µg/L in the final jar. The optimum dosage was selected at 90 mg/L. At this dosage the supernatant turbidity and colour were 0.14 NTU and 5 ACU respectively. The aluminum residual was 70 µg/L and the final pH was 7.63. The quality in jars with higher PACl dosages was similar to the jar with 90 mg/L. Again, the best floc was found in jars that were underdosed. The floc in jars with PACl dosages above 90 mg/L was not as big and strong as the floc in jars at 90 mg/L and less.

Run No. 6

In this run, pH was pre-adjusted to approximately 7.3 to 7.4 and then jars were dosed with PACl ranging from 40 to 140 mg/L. LT27A was added at 0.5 mg/L in all jars. The final pH in the jars ranged from 7.34 to 7.02. A minimum aluminum residual was not reached, but levels were very low, ranging from 44 to 23 µg/L. Supernatant quality did not improve significantly beyond a dosage of 100 mg/L, and was not better than runs without pre-adjustment of pH. Aluminum residuals were lower in this run compared to runs without pre-pH adjustment. The optimum PACl dosage was chosen to be 100 mg/L. Once again, it appeared that floc quality was better in underdosed jars.

5.4 CONCLUSIONS

The following are general conclusions drawn from the off-site jar testing evaluation:

- The optimum result for turbidity and colour removal in Series No.1 for "typical" raw water conditions was found when dosing PACl at 70 mg/L.

- For the raw water evaluated in jar test Series No.2 which was highly turbid and coloured due to storm runoff, the optimum PACl dosage was 90 mg/L.

- Aluminum residual in the final filtered water is very dependent on pH, although residuals well under 100 μg/L are attainable by dosing PACl alone and without pre-adjustment of pH.

- Testing indicated that pre-adjustment of pH made little difference in terms of optimum PACl dosage or floc quality. This aspect should be investigated in more detail before the municipality commits to the purchase of a pre-pH adjustment system.

- Better quality effluent was obtained at dosages somewhat higher than was required to produce good floc.

- The best polymer used with PACl was Percol LT27A. LT20 and LT24 are other good choice.

- There seems to be no advantage in switching to acidified alum based on water quality or optimum dosages.

6.0 ON-SITE TESTING

6.1 FILTER TO WASTE

Wasting treated water during the initial stage of a filter run is a procedure that is commonly used to lower the risk of re-introducing waterborne pathogens such as cysts in a water supply. Typically, during the initial stages of a filter run, the amount of particles in the filter effluent is elevated. Following this stage, the particulate level drops quickly and is stable over a long period. During the late stages of a filter run, the particulate level gradually increases and backwashing is required. The Warkworth plant was designed with the capability to filter to waste. In the present backwashing procedure, filter effluent is wasted after washing for 1 minute at a reduced rate. On-site work was done to assess what the filter to waste duration should be at normal filter rates.

Turbidity profiles were measured on the filter effluent on three occasions. A filter was put through its normal backwashing sequence and then placed into service. Samples were collected for turbidity measurements from the filter effluent pipe. This pipe was not under pressure, therefore, plastic tubing was inserted into a valve opening to intercept the filter effluent. A HACH 2100P turbidimeter was used for measurements. Samples were gently agitated before measurement to counteract any settling that may have occurred in the sample bottles. The measurements were made at the Warkworth plant shortly after sample collection.

The results for the first water sampling on filter No.1 are presented in Table 6.1.

TABLE 6.1 Filter to waste turbidity profile – Filter No.1 First water sampling

Warkworth Water Treatment Plant Filter to Waste Turbidity Profile (Filter No.1 - First Sampling)	
Elapsed Run Time (min)	**Filter Effluent Turbidity (NTU)**
1	0.93*
2	1.35
3	1.33
5	0.42
7	0.45
10	0.59
15	1.03
30	2.54
45	2.94
Location: Filter No. 1 Date: November 19, 1997 Raw Turbidity: 1.3 NTU Raw App. Colour: 29 ACU	

* May be low. Bottle was not agitated before measurement.

The Filter No. 1 (see Figure 3.1) was in service for two days before being backwashed. A pin floc was formed in the plant and none was being removed by the tube settlers. The filters were overloaded. The reason why turbidity is lower for the first 10 or 15 minutes is that the filter is treating water from the filter box and settling tank that has settled for hours after plant shutdown. The minimum turbidity level was reached at 5 minute mark.

The results for the water sampling on filter No.2 are presented in Table 6.2.

TABLE 6.2 Filter to waste turbidity profile – Water sampling on filter No.2

Warkworth Water Treatment Plant Filter to Waste Turbidity Profile (Water Sampling on Filter No.2)	
Elapsed Run Time (min)	**Filter Effluent Turbidity (NTU)**
1	1.11
2	0.88
3	1.46
4	0.49
5	0.33
7	0.46
10	0.31
15	0.46
20	0.60
30	0.64
60	1.32
Location: Filter No. 2 Date: February 16, 1998 Time: 9:00 Raw Turbidity: 1.3 NTU Raw App. Colour: 32 ACU	

The filter No.2 was due for a backwash. The performance was better than measured for filter No.1 on November 19. Regardless, the minimum turbidity level was also achieved after 5 minutes filtration.

To verify the performance of filter No.1, a turbidity profile was performed again. The results for the water sampling are presented in Table 6.3.

TABLE 6.3 Filter to waste turbidity profile – Filter No.1 second water sampling

Warkworth Water Treatment Plant Filter to Waste Turbidity Profile (Filter No.1 – Second Water Sampling)	
Elapsed Run Time (min)	**Filter Effluent Turbidity (NTU)**
1	0.72
2	0.64
3	0.65
4	0.30
5	0.18
7	0.29
10	0.31
15	0.15
30	0.46
Location: Filter No.1 Date: Feb.16/98 Time: 10:30 Raw Turbidity: 1.3 NTU Raw App. Colour: 32 ACU	

The filter was halfway through its run prior to backwash, hence the lower turbidities than filter No.2. Once again, the minimum turbidity level was achieved at 5 minutes.

The sampling has shown that the filter to waste period, should it be implemented, would have to be a minimum 4 to 5 minutes but could be longer. Further testing is required when the plant process has been optimized to confirm this period. The data also shows that turbidity breakthrough occurs early in the filter run. This is likely due to the poor flocculation and settling performance of the plant, especially during the cold water period. Measures such as optimized polymer selection and addition, optimized mixing, and pre-pH adjustment for coagulation should be beneficial in improving the quality of the clarifier supernatant prior to entering the filters. The early turbidity breakthrough is not detected by routine sampling of plant effluent; settling is probably occurring in the clearwell before the high lift sampling point.

6.2 POLYMER FEED TRIALS

The plant has facilities for polymer addition consisting of a day tank, feed pump, and a system for diluting polymer solution before injection. The point of addition is in the pipe that feeds the package plant, after coagulant addition and 2 to 3 metres before the pipe enters the flocculation tanks in the package plant.

The plant has historically used a liquid polymer (Allied Colloids Percol LT35) as a coagulant aid. The operator has indicated that it has never been effective in building a suitable floc. The floc that is formed is tiny and difficult to settle, especially in winter when temperatures and turbidity are lowest. Jar testing conducted by MOE in 1997 in support of this study (Section 5.0) also indicated that LT35 is a very poor coagulant aid compared to nearly all other polymers that were investigated. The manufacturer also indicated that the Percol liquid polymers are designed to function as coagulants and should not be expected to build a strong floc. For these reasons, an alternative polymer is needed to improve floc formation and settling.

There are no facilities at Warkworth for solution makeup using dry polymers. As a result, solutions were prepared at the MOE laboratory and immediately sent to the plant. Recommended solution life is 48 to 72 hours; the trials were completed within three days of makeup. The feed solution was made to a concentration of 0.5 mg/L. It would not have been possible to feed polymer solutions of a lower concentration at the required dosages because of the small size of the feed pump. At the normal plant flow rate of 14.2 L/s (1,232 m^3/d) with a 0.5% solution, a dosage of almost 0.4 mg/L is achieveable. The feed pump for PACl is also small; the maximum achieveable dosage at the normal plant flow rate is 65 to 70 mg/L.

Trial No.1

The first trial began on the afternoon of December 3, 1997. The feed solution used was a 0.5% solution of Percol LT20. A time/displacement test confirmed that the feed pump was delivering 68 mL/min which was equivalent to a dosage of 0.38 mg/L at the plant flow rate of 14.2 L/s.

The PACl dosage was initially set at 40 mg/L. There was a little improvement over normal treatment in terms of the amount of floc produced, but settling was still very poor and did not improved.

On December 4 the operator increased the PACl dosage to 60 mg/L. There was further improvement in the quantity of floc, but not in the quality. A summary of filter influent and effluent turbidity is presented in Table 6.4.

TABLE 6.4 Polymer Trial No.1

Warkworth Water Treatment Plant Polymer Trial No.1		
Time	**Filter Influent Turbidity (NTU)**	**Filter Effluent Turbidity (NTU)**
13:00	2.58	0.19
14:00	3.65	1.25
15:10	3.51	1.83
16:30	3.15	-
18:20	0.16	-
Data from Thursday Dec. 4, 1997 PACl dosage = 60 mg/L. LT20 dosage = 0.38 mg/L. Plant run automatically started at 12:30 and shut down automatically at 16:20.		

At this point, it was felt that the floc may be forming in the pipe between the point of polymer addition and the package plant, and that the mixing in the first tank may have been breaking up any formed floc. Therefore, the mixer in the first tank was shut off on December 5. The operator reported that some of the floc was larger, but there was still a significant amount of fine floc that would not settle. The supply of polymer was exhausted and the trial ended.

Trial No.2

The second trial began on the afternoon of December 17, 1997. The feed solution used was a 0.5% solution of Percol LT24. A time/displacement test again confirmed that the feed pump was delivering 68 mL/min which was equivalent to a dosage of 0.38 mg/L at the plant flow rate of 14.2 L/s.

Jar testing had shown that LT24 should give a performance similar to LT20. It was planned to feed PACl at 60 mg/L and shut off the first mixer to duplicate the conditions that existed at the end of the first trial. It was observed that floc formation and settling were the same, or possibly not quite as good as that experienced with LT20 in the first trial.

It was then decided at the end of the day to lower the plant flow rate from 14.2 to 12 L/s to increase residence time in the floc tanks and lower the surface overflow rate in the settling tank, and hopefully improve floc formation and settling. On the morning of December 18, the operator lowered the plant flow rate to 12 L/s and shut off the paddle mixer in the first flocculation tank. At this time, the operator observed that the floc coming from the inflow pipe and into the first floc tank was better than the floc in the second tank, meaning that the mixer in the second flocculation tank was breaking up the floc. The mixer in the second tank was then shut off.

The effect of these changes was significant. The floc was much larger and settling improved, as evidenced by lower filter influent turbidity than trial No.1. The operator also measured filter effluent turbidity and noted that even by the end of the run (4 hours) the turbidity was in the range of 0.5 to 0.6 NTU. The results are presented in Table 6.5. This was a vast improvement over the first trial, where the filter effluent turbidity was approximately 2 NTU after 4 hours. It was not possible to tell if the improvement was due to the 20% reduction in plant flow rate, shutting down the two mixers or a combination of both.

TABLE 6.5 Polymer Trial No.2 – Dec. 17, 1997

<table>
<tr><th colspan="3">Warkworth Water Treatment Plant
Polymer Trial No.2 – Dec. 17, 1997</th></tr>
<tr><th>Time</th><th>Filter Influent Turbidity (NTU)</th><th>Filter No.2 Effluent Turbidity (NTU)</th></tr>
<tr><td>14:00</td><td>0.31</td><td>N/A*</td></tr>
<tr><td>14:15</td><td>0.31</td><td>N/A*</td></tr>
<tr><td>14:30</td><td>2.9</td><td>1.47</td></tr>
<tr><td>15:30</td><td>4.27</td><td>0.07</td></tr>
<tr><td>16:45</td><td>1.65</td><td>0.11</td></tr>
<tr><td>17:45</td><td>1.64</td><td>0.12</td></tr>
<tr><td>19:45</td><td>1.66</td><td>0.53</td></tr>
<tr><td colspan="3">Data from Thursday Dec. 18, 1997
PACl dosage = 60 mg/L. LT24 dosage = 0.38 mg/L.
Plant flow rate cut back to 12 L/s. Filter No.2 backwashed between 14:30 and 15:30 on Dec. 18.</td></tr>
</table>

* N/A - plant not running yet

On December 19 a similar performance was observed. The results are summarized in Table 6.6.

TABLE 6.6 Polymer Trial No.2 – Dec. 19, 1997

Warkworth Water Treatment Plant Polymer Trial No.2 – Dec. 19, 1997			
Time	**Filter Influent Turbidity (NTU)**	**Filter Effluent Turbidity (NTU)**	
		Filter No.1	**Filter No.2**
12:45	1.64	1.45	0.10
13:45	1.65	0.07	0.21
14:50	5.22	0.07	0.89
Data from Friday Dec. 19, 1997 PACl dosage = 60 mg/L. LT24 dosage = 0.38 mg/L. Plant flow rate cut back to 12 L/s. Plant started at noon and Filter No.1 backwashed at 12:50. Polymer supply exhausted at 15:00.			

Additional polymer trials were conducted in May and June 1998 using LT20 and LT27A. Polymer solutions were prepared using the new dry polymer make-up and feed system. The goal was to see if a settleable floc could be formed. Results were disappointing; a settleable floc could not be formed. The plant was turned down to 10 L/s to increase retention time, and the polymer feed point was moved to the inlet to the first flocculation tank.

6.3 RECOMMENDATIONS

Further study is recommended to evaluate the impact of relocation of the polymer, shutting down mixers in the first flocculation tanks, and lowering plant flow rate. A polymer make-up system with adequately sized feed pump and day tank is also needed. This equipment was purchased by the MOE at the end of March 1998.

7.0 CONCLUSIONS

Historical data for 1996 indicated the colour in the treated water varied from 2 to 11 TCU for an average of 5 TCU, which meets the Ontario Drinking Water Objective (ODWO) of 5 TCU. The monthly average colour exceeded 5 TCU for a total of three months in 1996. High levels of colour in the raw and treated water present a higher potential for THMs formation since organics in the water will react with free chlorine to form THMs.

High levels of THMs were observed in July, September and October of 1996. The average THMs values for that year in the treated water and the distribution system were 148 and 121 μg/L respectively, which is in excess to the new ODWO guideline of 100 μg/L. Stopping pre-chlorination will help to reduce level of THMs in the treated water.

The raw water turbidity is variable and ranged from 0.8 to 5.8 NTU with peak values measured in the summer and the fall. The turbidity in the treated water ranged from 0.1 to 0.9 NTU for an average of 0.4 NTU. The turbidity is below the ODWO of 1.0 NTU, but remains above the objective for this study of 0.1 NTU after the filter effluent for protection against cryptosporidium and giardia. Optimization of chemical dosage and coagulant aid selection will help improving floc formation and improve turbidity removal.

The pH of the raw water has an average of 8.0. There is no pH adjustment performed on the raw water therefore the pH of the treated water remains almost the same with an average pH of 7.9.

The aluminum residual in the treated water was widely variable and ranged from 10 to 1,900 μg/L. The ODWO for aluminum in the treated water is 100 μg/L. This guideline is not health related but is an operational guideline set to reduce post precipitation of alum in the distribution system. Trial testing to perform pH adjustment of the raw water would be useful in determining its impact on aluminum residual in the treated water.

For proper inactivation of giardia cysts, the free chlorine concentration required during the winter condition, when the water temperature is around 0.5 °C is 0.74 mg/L measured at clearwell exit. The minimum free chlorine concentration required during the summer for a water temperature of 20 °C is 0.19 mg/L. The free chlorine residual entering the distribution system was maintained at approximately 1 mg/L during the summer of 1997 by the existing post-clearwell chlorine feed. The operator should adjust the chlorine feed rate of the proposed filter effluent feed point to try to achieve the required free chlorine residual (see Table 4.3). The operator should always ensure that enough chlorine is added at the existing post-clearwell feed point to maintain a free chlorine residual of 0.2 to 0.3 mg/L at the end of the distribution system.

8.0 RECOMMENDATIONS

The following modifications to the Warkworth plant operation are recommended to improve the overall plant performance:

1. Stop pre-chlorination to the wetwell to reduce THMs formation.
2. Install a new post-chlorine injection system at the filter effluent to provide sufficient contact time in the clearwell for inactivation of cysts and viruses.
3. Modification to the backwash procedure.
4. Stop discharging the wastewater supernatant to the wetwell, and discharge it to the creek to reduce the potential for reintroducing cryptosporidium to the water supply.
5. Install on-line turbidimeters for the raw water and the filter effluent to help staff respond quickly to water quality changes.
6. Perform CO_2 full scale trial testing to lower the pH of the raw water.
7. Reduce plant flow rate to improve flocculation.
8. Switch to a dry polymer feed system.

8.1 STOP PRE-CHLORINATION OF THE RAW WATER

The Total Organic Carbon (TOC) concentration for the raw water based on water sampling performed in the summer 1997 varies between 2.5 to 8.7 mg/L, which indicates a relatively high level of organics in the raw water at times. It is expected that stopping pre-chlorination will lower the THMs formation since during pre-chlorination, chlorine is added at a location where the level of organics is maximum, before any removal occurs through the clarifier and the filter. This will help greatly to comply with the new ODWO of 100 μg/L for THMs in the treated water.

The practice of pre-chlorination has been established for a long time in Ontario. It appears however that it should be re-examined for many plants facing THMs problems. Pre-chlorination may be required to improve the overall process performance for some plants, and sometimes, for inactivation of coliform when the contact time available in the clearwell is not sufficient for proper inactivation. This is not the case for Warkworth. Usually, pre-chlorination is performed to reduce biological fouling on the equipment and more specifically on the filter. However, performing intermittent chlorination on an as-needed basis (once or twice a year if needed), instead of pre-chlorinating on a continuous basis, will have a great impact on reducing the level of THMs formation. Biological fouling and formation of mud balls in the media will increase the initial filter head loss over time. Therefore, verifying the initial head loss after filter backwash would help determine when it is time for shock chlorination of the filters. It is therefore recommended to leave in place the pre-chlorination dosing equipment.

The original pre-chlorination system was taken out of service in early May 1998 and remains in a standby mode should periodic pre-chlorination be needed to control growths in the package plant tankage. As a result THMs quenched in the distribution system (Town Hall) for the summer of 1998 were:

May 27 - 74 µg/L (20°C)
June 11 - 87 µg/L (18°C)
June 26 - 120 µg/L (24°C)
July 24 - 115 µg/L (24°C)
July 29 - 86 µg/L (23°C)

There have been no apparent problems caused by lack of pre-chlorine. In addition the plant flow has been turned down to 10 L/s, from 15 L/s.

The average THMs level for the summer of 1998 was 96 µg/L, compared to 125 and 133 µg/L for the summers of 1997 and 1996 respectively, showing an improvement during 1998. Also, given lower winter concentrations, it is expected that the THMs level will be under 100 µg/L as an annual average.

8.2 NEW POST-CHLORINE INJECTION AT THE FILTER EFFLUENT

To make use of the contact time available in the clearwell for proper inactivation of cysts and viruses prior to the first customer, it is strongly recommended that the post-chlorine injection be relocated to the filter effluent. To simplify the installation of the dosing system, it is recommended to inject the chlorine solution directly in the filter effluent pipes. The installation of a chlorine injection system in the clearwell would be more difficult and would involve interruption of plant operation.

The chlorine solution could be injected in the 150 mm diameter horizontal pipe section located before the 100 mm elbow pipe going down into the clearwell. Two injection points will be required, one for each filter. The dosing equipment will include the following components:

- 1 day tank,
- 2 dosing pumps,
- 2 back pressure and 2 pressure relief valves,
- 2 suction assemblies with foot valves and level switch,
- piping and fittings.

The new post-chlorination system at the filter effluent was installed during the spring of 1998. A copy of the amendment to the certificate of approval is in Appendix C. It was recommended to keep the existing post-chlorine injection system at the high lift pump header, to have the flexibility to increase the chlorine dosage if needed to maintain adequate chlorine residual in the distribution system.

The operation of the dosing pumps is controlled by the position of the filter effluent valves through a limit switch installed on each valve. Prior to performing a backwash, the filter effluent valve closes which automatically turns off the corresponding dosing pump. This is done to avoid discharging concentrated chlorine solution into an empty pipe to reduce corrosion problems. The chlorine dosage onto the clearwell is controlled manually, and is done to achieve a pre-determined free chlorine residual measured at the end of the clearwell in cell No.4 (refer to Table 4.3 for proposed free chlorine residual for different raw water temperature). This may be difficult to do accurately because of the long time delay between the chlorine dosage point and the point of free residual measurement.

Grab samples will be collected from cell No.4 via an access hatch to determine the free chlorine residual. The sample will be analyzed using the plant's DR700 spectrophotometer. The frequency should be once per day and the measurement should be made near the end of an operating cycle and not when the plant has been out of operation for several hours. The plant daily log sheet should be changed to enable the recording of this measurement.

8.3 MODIFICATION TO THE BACKWASH PROCEDURE

The present backwash procedure performed at the plant is described as follows:

- The raw water flow is throttled from 14.2 L/s to 8.1 L/s.
- The filter to be washed is shut down.
- The surface wash comes on for 10 seconds.
- A low rate backwash runs for 50 seconds.
- Surface wash is stopped.
- A high rate backwash of 2,400 L/min runs for 5 minutes.
- Backwash is stopped.
- Filter effluent at low rate is discharged to the wastewater collection system for 1 minute.
- Raw water flow is increased to 14.2 L/s.
- Filter effluent is discharged to the clearwell.

The procedure described on the previous page indicates that there is a filter to waste step performed during the backwash at low rate for 1 minute. Filter to waste is performed by putting the filter back to its filtering mode for a certain time, while discharging the filtered water to the wastewater collection system. On-site testing indicated that this filter to waste procedure should be increased to a minimum of 5 minutes and possibly longer, subject to further testing, to improve the overall filter effluent turbidity, since higher turbidity levels were observed shortly after a backwash. The piping system is in place at the Warkworth plant to be able to extend the filter to waste duration. However, it would require some minor programming modifications to the existing Klockner Moeller-PS3 control system.

8.4 WASTEWATER SUPERNATANT DISCHARGE TO MILL CREEK

It is recommended to stop returning the wastewater supernatant to the wetwell and to discharge it to the creek, to reduce the potential for reintroducing cryptosporidium cysts to the water supply. Returning the supernatant to the wetwell can re-cycle pathogens that have already been removed by the filters.

Returning the supernatant to the creek can be done by simple piping modifications which involves connecting the existing discharge pipe to an existing sump located beside the building. This sump discharges by gravity to the creek downstream of the intake.

The piping and accessories required are described as follows:

- Approximately 7 m of 200 mm diameter stainless steel pipe
- Two 200 mm butterfly valves
- One sampling tap
- Accessories

The supernatant discharge would be initiated when the ultrasonic level located in the tank reaches a high water level. Discussions with the MOE Approvals Branch indicates that the supernatant will be subject to quality monitoring regarding suspended solids and total chlorine residual. It is expected that the suspended solids in the supernatant will comply to an annual average of 15 mg/L or less. The current chlorine residual concentration in the supernatant (approximately 0.1 mg/L total chlorine) will decrease during its passage through the discharge sump and the discharge pipe. The chlorine concentration at the discharging point will further decrease due to dilution from the creek water flow. It is therefore expected that the very low chlorine concentration in the receiving stream would have a negligible impact on the receiving stream.

A sampling tap will be installed on the new discharge line. Testing should be done at the plant to correlate the suspended solids concentration to turbidity for rapid in-house monitoring of the supernatant quality. There will need to be an amendment to the Certificate of Approval prior to discharging the supernatant to the creek.

8.5 IN-LINE TURBIDITY METERS

The raw water is subject to high variations of turbidity and colour depending on the time of the year or the weather conditions. The installation of in-line turbidity meters would be recommended to monitor the variations and quickly respond by adjusting chemical dosage for better plant performance. It is therefore recommended to install an in-line turbidity meter for the raw water, and one in-line turbidity meter for each filter effluent, for a total of three (3) turbidity meters.

It is preferable to install the turbidity meter at the filter effluent instead of the plant effluent to help responding faster to a deterioration in water quality, since it will take hours before an event is detected at the end of the clearwell. In-line turbidity meters would also help monitoring the filter performance, and could be used to indicate the appropriate moment to initiate a filter backwash.

It would also be recommended to install a 3-pen recorder to keep track of the turbidity variation when there is no operator at the plant.

8.6 CO_2 FULL SCALE TRIAL TESTING

It is recommended to undertake full scale testing with carbon dioxide (CO_2) for pH adjustment of the raw water. The advantage of using CO_2 over a strong acid such as sulfuric is that CO_2 is much easier and safer to use and it allows a more controlled lowering of the pH without over shooting the optimum. The raw water pH may need to be reduced to around 7.5 for better chemical treatment performance.

The benefits of using CO_2 are summarized as follows:

- Lower levels of aluminum residual in the treated water.
- Optimization of chemical dosage with reduced level of turbidity and colour in the treated water.
- Reduce THMs formation.
- Improve the disinfection process.

Performing raw water pH adjustment with CO_2 to improve plant performance, particularly to lower the level of aluminum residual when dosing PACl, is gaining popularity. Systems are in place and operating for a few years at the Township of Tay, Lindsay Water Treatment Plant and permanent installation will be implemented at the Keswick Water Treatment Plant in 1998.

The recommended duration for the full scale testing is 4 weeks. CO_2 should be injected in the low lift pump header before the injection of PACl. As much separation as possible should be made between CO_2 and coagulant addition.

The equipment required for the testing are the following:

- 1 (one) manual flowmeter,
- 1 (one) valve for CO_2 control,
- 1 (one) solenoid valve,
- 1 (one) diffuser to be installed in the low lift header line,
- 1 (one) relief valve system for safety,
- 1 (one) vapourizer,
- and CO_2 cylinders or mini-bulk tanks for indoor or outdoor installation.

8.7 REDUCE PLANT FLOW RATE

To improve floc formation in the flocculation tanks and the ability for the floc to settle in the clarifier, further testing should be performed at reduced plant flow rates. The flow rate can be decreased by throttling the low lift pump, which will extend the hours of plant operation. The package plant is currently operated only 8 hours per day. As demonstrated during on-site testing by the MOE staff, it was found beneficial to decrease the flow rate by 20%. It is expected that a further decrease will be even more beneficial for particulates and colour removal. It is recommended to throttle the raw water pumps so that the package plant run time is extended to 16 to 20 hours.

The optimization of flocculation tanks operation to reduce floc shearing should also need to be evaluated further by doing on-site testing to reduce pin floc formation and floc carry over to the filters.

8.8 SWITCH TO DRY POLYMER FEED SYSTEM

It is recommended to change the existing polymer feed system using Percol LT35 to a dry polymer feed system using LT27A or LT20 to improve the floc formation as demonstrated during off-site and on-site testing. The injection point should also be relocated to immediately before the first flocculation tank to reduce floc shearing in the low lift header line. The equipment was purchased by the MOE in March of 1998. Installation and commissioning was completed by May 1998. The manual dry polymer feed system purchased is described as follows:

- 1 (one) clamp-on propeller mixer,
- 1 (one) 270 L day tank,
- 1 (one) Hootenanny Eductor
- 1 (one) metering pump with accessories,
- and 1 (one) weigh scale – 2 kg capacity.

9.0 COST ESTIMATE FOR IMPLEMENTATIONS

The installation of the post-chlorine injection at the filter effluent was been done in the winter of 1998. The equipment required to prepare a polymer solution from a dry powder was installed in May 1998. The equipment was purchased by the MOE and the cost involved is summarized as follows:

• New post-chlorine injection system at the filter effluent:	$ 4,340
• Manual dry feed polymer system:	$ 5,300
Total cost (Taxes not included):	**$ 9,640**

It is expected that by stopping pre-chlorination this will translate to a potential saving of up to 50% in chlorine cost.

A summary of the cost estimate for the installation of a new piping system to discharge the wastewater to the creek, the installation of in-line turbidity meters and one recorder, and for CO_2 full scale trial testing for pH adjustment of the raw water is presented in Table 9.1. The cost estimate is summarized as follows:

• New piping system for supernatant discharge to Mill Creek:	$ 5,000
• Installation of three in-line turbidity meters and one 3-pen recorder:	$ 9,000
• CO_2 full scale trial testing:	$ 5,000
Total budget cost (Taxes not included):	**$19,000**

TABLE 9.1 COST ESTIMATE FOR WARKWORTH WATER TREATMENT PLANT

I- BUDGET COST FOR THE INSTALLATION OF NEW PIPING TO DISCHARGE THE SUPERNATANT TO THE CREEK

DESCRIPTION	UNIT COST		QUANTITY		COST
200 mm SS Pipe	$73	/m	7	m	$511
200 mm Butterfly Valve	$500	/valve	2		$1,000
200 mm 90° Elbow	$85	/elbow	1		$85
Fabrication	$2,000				$2,000
Installation	$1,500				$1,500
Sub-Total:					$5,096
				Say	$5,000

II- IN-LINE TURBIDITY METERS & RECORDER

DESCRIPTION	UNIT COST	QUANTITY	COST
In-line Turbidity meter with 3 Reading Points (Turbidity meter 1720D)	$5,600	1	$5,600
3-pen Recorder	$2,900	1	$2,900
Installation	$500		$500
Sub-Total			$9,000

GLOSSARY AND LIST OF ABBREVIATIONS

Alum : aluminum sulphate

CT : Value required to achieve adequate inactivation and/or removal of cysts and viruses. T is the time (in minutes) it takes the water during peak hourly flow, to move between the point of disinfectant and a point where C, the residual disinfectant concentration (mg/L), is measured prior to the first customer.

d : day

°C : degree Celsius

DWSP : Drinking Water Surveillance Program

ECR reagent : Eriochrome Cyanine R

FID : Flame Ionization Detector

ft : foot

G : flocculation energy gradient

Gt : flocculation energy

GC/MS : Gas Chromatograph / Mass Spectrometry

GAC : Granular Activated Carbon

g : gram

h : hour

HFS : hydroxylated ferric sulphate (Ferriclear)

ICP : Inductively Coupled Plasma Atomic Emission Spectoscopy

IG : imperial gallon

kW : kilowatt

L : litre

L/cap.d : litres per capita per day

L/s : litres per second

m : metre

m^2 : square metres

m^3 : cubic metres

m^3/d : cubic metres per day
m/h : metres per hour (equivalent $m^3/m^2.h$ - filtration rate)
µg/L : micrograms per litre
mg/L : milligrams per litre
mm : millimetre
mL/min : millilitres per minute
min : minute
NTU : Nephelometric Turbidity Unit
OCWA : Ontario Clean Water Agency
ODWO : Ontario Drinking Water Objective
% : percent
PACL : polyaluminum chloride
PVC : polyvinyl chloride
lb : pound
rpm : revolution per minute
SOR : Surface Overflow Rate
SWTR : Surface Water Treatment Rule
T_{10}/T : This factor describes the baffling condition in the clearwell, and represents the ratio between T_{10}, which is the time it takes 10 percent of a dye or tracer to be detected at the basin outlet after it is injected into the basin influent flow, and the theoretical detention time for plug flow in pipelines and flow in a completely mixed chamber.
TOC : Total Organic Carbon
THMs : Trihalomethanes
TCU : True Colour Unit
W/V : weight/volume

REFERENCES

American Water Works Association Research Foundation - Optimizing Chloramine Treatment, 1993.

Environmental Science and Engineering Magazine. Drinking water Update - The Facts About Human Health and Aluminum in Drinking Water, January, 1997.

U.S. Environmental Protection Agency, Science and Technology Branch Criteria and Standards Division of Drinking Water. Guidance Manual for Compliance With the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources, October , 1990.

Ontario Ministry of the Environment, Environmental Approvals and Land Use Planning Branch. Guidelines for the Design of Water Treatment Works, April 1982.

APPENDICES

Plant Survey

Appendix A

PLANT: WARKWORTH WATER SUPPLY PLANT
Shipping Address: Town of Percy, Police Village of Warkworth
40 Main Street, P.O. Box 129, Warkworth, ON, K0K 3K0

Tel: (705) 924-2931 Fax: (705) 924-3139

PREPARED BY: L.Fortin

DATE: May 29, 1997

STAFF:
Superintendent: Ralf Switzer
No. of Operators: 1
Staff Work Schedule: 21 h/week (3h/d), Mon. to Sun.

Names of Operators:
Steve Meacock (operator in training)
Certified Y/N: 1

PLANT CAPACITY:
Average Daily Flow: 308 m^3/d
Maximum Daily Flow: 488 m^3/d
Rated Plant Capacity: 1,232 m^3/d
Hours of plant operation: 7 to 8 h/d (all year)
Population Served: 650

OPERATING AUTHORITY:
Township of Percy

YEAR OF CONSTRUCTION: 1992

SOURCE OF RAW WATER: Mill Creek

RAW WATER CHARACTERISTICS:
- Colour: 5 to 100 TCU
- Turbidity: 1 to 5 NTU
- pH: 7.8 to 8.3
- Alkalinity: 208 mg/L - $CaCO_3$

CHEMICALS:

- Coagulant:
  Type: PACL
  Dosage: 20 mg/L (Summer and Winter)
  Injection Point: In-line mixer located in the low lift header

---

- Coagulant Aid:
  Type: Percol LT 35 (Liquid)
  Dosage: 0.5 mg/L
  Injection Point: Low lift header after the in-line static mixer

---

- Alkalinity/pH Adjustment:
  Chemical Used: Not Applicable
  Dosage: mg/L (Summer), mg/L (Winter)
  Injection Point:

- Disinfection:
  Type: Sodium Hypochlorite
  Pre-Desinf. Dosage: 1.5 to 2.1 mg/L
  Post-Desinf. Dosage: 1.4 to 2.3 mg/L
  Injection Point: Pre-Desinf. in the wetwell. Post-Dinsinf in high lift pumps header.

ANALYSIS DONE AT THE LAB:

• pH • Colour • Turbidity
• Chlorine Residual • Aluminum Residual

LAB EQUIPMENT AVAILABLE:
• Jar Test (Phibbs & Bird) • 2 Hach DR 100 Colorimeter for aluminum residual and chlorine residual • Hach pHmeter • DR 700 (Colour) • Hach 2100 A (Turbidity)

PROCESS CONFIGURATION:

CHEMICALS METERING:

	TYPE	CAPACITY	CONTROL	CONDITION
• Coagulant:	PACL 2 metering pumps (1 duty and 1 standby pump)		Signal from the PLC in response to low lift pump starting	
• Coagulant Aid:	Percol LT35 1 LMI Pump		Signal from the PLC in response to low lift pump starting	
• Alkalinity /pH Adjustment:	N/A			
• Disinfection:	- Pre: 1 LMI Series A75, 3.8 L/h @760 kPa		- Signal from the PLC in response to low lift pump starting. Dosage is controlled by manually adjusting the stroke length.	
	- Post: 1 Aldos		- Signal from the PLC in response to high lift pump starting. Post- chlorination is controlled through the flow meter (420 mA).	
• Other:	N/A			

PROCESS CONFIGURATION (Continued):

INTAKE:	TYPE				CONDITION	NOTES
	250 mm diameter cast iron, 25 m long pipe and intake structure equipped with a bar screen and a fine screen (6 mm openings).					
SCREENING:	TYPE	NO	DIMENSIONS		CONDITION	NOTES
	Manual Vert. Bar Screen	1	450 mm Height (75 mm Mesh)			
LOW LIFT PUMPS:	TYPE	NO		CAPACITY	CONDITION	NOTES
	Flygt Submersible Pumps	2		14.3 L/s each @ TDH of 7.8 m (2.4 kW)		
HIGH LIFT PUMPS:	TYPE	NO		CAPACITY	CONDITION	NOTES
	Fairbanks Morse Vertical Turbine	3		10.8 L/s each @ 46 m TDH (7.5 kW)		
MIXING:	TYPE	NO	DIMENSIONS		CONDITION	NOTES
	Koflo In-Line Static Mixer	1	316 SS 150 mm diam., 752 mm long			Equipped with blades to mix the chemicals.
FLOCCULATION:	TYPE	NO	DIMENSIONS	VELOCITY GRAD.	DETENTION TIME	NOTES
	Mechanical Floc. Paddle wheel mixers	3 Stage	First two: 1.36m x 1.22m Third: 2.73m x 2.44m	$6.85\ s^{-1}/6.85\ s^{-1}/3.4\ s^{-1}$	28 min @ Des. Flow (1,232 m^3/d)	First two:Cons. Speed Third: Var. Speed
CLARIFICATION:	TYPE	NO	DIMENSIONS	VOLUME	DETENTION TIME	NOTES
	60° Tube Settlers	1	6.7m x 2.7m x 2.44m depth Total surface: 18.2 m^2	44.1 m^3	52 min @ Des. Flow Overflow rate: 2.84 m/h	Sludge blowdown operated on timer
FILTERS:	TYPE	NO	DIMENSIONS	FILTRATION RATE	DETENTION TIME	NOTES
	Constant Head Gravity Filters	2	2.5m x 1.35m each Filt. surface: 3.4 m^2 each	7.5 m/h @ Design Flow	19 min	Anthra./Sand/Gravel Surface Wash System
CLEARWELL/: ON-SITE RESERVOIR	TYPE	NO	DIMENSIONS	VOLUME	BAFFLED: Y/N	NOTES
	Clearwell	1		480 m^3	Y	4 cells
	In-ground Res.	1		506 m^3		

PLANT CONTROL:

- Flow (Manual Set/Auto):
- Level: The low lift pumps operation is initiated by the water level in the clearwell by using an ultrasonic level transducer.
  The operation of the high lift pump is provided by level sensing equipment located in the in-ground floating reservoir and a telephone link from the sensor for the plant PLC.
- On/Off:

PROCESS MONITORING:

	INSTRUMENT	MONITORING FREQUENCY	LOCATION	NOTES
• Turbidity:	Hach 2100 A		Raw and Treated	
• pH:	Hach pHmeter		Raw and Treated	
• Free Chlorine Residual:	EIT in-line Chlorine Analyzer	Continuous	Plant Effluent	
• Aluminum Residual:	Hach DR 100 Colorimeter		Treated	
• Colour:	DR-700		Raw and Treated	

ISSUES:

- The raw water is subject to change quality with rain fall, and tends at time, to be excessively turbid and highly coloured.
- Due to the nature of the source, raw water bacterial counts often exceed the ODWO guidelines.
- High variation of aluminum residual with maximum value observed around 300 ug/L in the treated water.
- Need for jar testing to improve treated water quality by testing CO_2, acidified alum, alum, and optimizing polymer type and dosage.
- The recirculation of supernatant from the sludge tank should be terminated, and supernatant should be returned to the river.
- Post chlorination is presently done at the high lift pump header. It should be done at the filter effluent to provide chlorine contact time through the clearwell.
- Installation of in-line turbidimeter for the raw and the treated water would be recommended to help predicting raw water quality change and respond quickly by adjusting chemical dosages.
- Some floc carry over was observed during the plant tour. However, the water above the filters was clear.

CHECK LIST:

✓ Copy of Certificate of Approval. OK

✓ Copy of DWSP report if available.

✓ Copy of monthly flows for the previous year. OK

✓ Copy of the monthly analysis for the previous year to evaluate plant performance for the raw water, settled water and plant effluent.

Analysis of interest are: DOC, true colour, turbidity, pH, alkalinity, aluminum residual, chlorine residual, temperature and THMs.

Off-Site Treatability Testing

Appendix B

TABLE: WARKWORTH WTP DATE: Sept. 23/97

TREATABILITY STUDY OBJECTIVE
Compare PACl vs. Acidified Alum
Compare Various Polymers
Effect of Treatment on Final pH. (PACl vs. various acid. alum products)

RAW WATER SOURCE :

JAR TEST CONDITIONS				RAW WATER QUALITY	
TREATMENT MODE:				TEMPERATURE	12°C
FLASH MIX :	TIME	- 2	MIN	ALKALINITY	216 MG/L
	SPEED	- 100+	RPM	PH	8.20**
FLOCCULATION:	TIME	- 20	MIN	TURBIDITY	1.5 FTU
	SPEED	- 20	RPM	COLOUR	33 TCU
SEDIMENTAION:	TIME	- 30	MIN		

FILTER MEDIA: Whatman 541

CHLORINE DEMAND					TTHM FORMATION POTENTIAL			
JAR #	CL2 MG/L	FREE MG/L	TOTAL MG/L		JAR #	CL2 MG/L	TTHM UG/L	
1								
2								
3								
4								
5								
6					RESULTS OF A 7 DAY FORMATION POTENTIAL TEST			
	mg/L	mg/L	mg/L		TTHM:TOTAL TRIHALOMETHANES			

ADDITIONAL COMMENTS:

Plant is a Napier-Reid package plant with mechanical tapered flocculation, tube settlers and dual-media filters.

-pH not measured because our meter is NFG.

NOTE: remember to try LT35 @ high
dosage; at a 40% dilution [illegible]
at 1.25 mg/L instead of 0.5 mg/L

Ontario Ministry of Environment & Energy
Central Laboratory - 125 Resources Road
FINAL REPORT (manager)
Oct 28, 1997 11:51 am
Login: C46919

FINAL ANALYTICAL RESULTS

Field ID: WK-JT-R
Sample ID: C46919-0001
MOEE*LIMS ID: 97WD39-00051
Station ID:
Collect Date: 25-SEP-97
Sample Location Description: RAW WATER

Sample Comments Description:

FIRST SERIES OF JAR TESTS ·
WARKWORTH

Listid	Parameter	Value	Units	Qual	Rmks
3016L1	Chloride	6.8	mg/L		
3172L1	Sulphate	14.5	mg/L		
3188L4	Solids; dissolved	268.	mg/L		CRO
3217L1	Calcium	74.0	mg/L		
	Magnesium	12.0	mg/L		
	Sodium	5.6	mg/L		
	Potassium	1.05	mg/L		
	Hardness	234.	mg/L		
3218L1	Conductivity	407.	uS/cm		
	pH	8.52	none		
	Alkalinity; total fixed endpt	224.	mg/L CaCO		
3219L1	Colour; true	25.8	TCU		
3247L1	Carbon; total organic	4.8	mg/L		
3274L1	Langeliers index calculation	1.4	none		
	Saturation pH Estimated	7.16	none		
3311L1	Turbidity	1.57	FTU		
3364L1	Nitrogen; ammonia+ammonium	0.006	mg/L	<T	
	Nitrogen; nitrite	0.002	mg/L	<T	
	Nitrogen; nitrate+nitrite	0.235	mg/L		
	Phosphorus; phosphate	0.0145	mg/L		
3367L1	Phosphorus; total	0.022	mg/L		

Field ID: WK-JT-R
Sample ID: C46919-0001
MOEE*LIMS ID: 97WD39-00051
Station ID:
Collect Date: 25-SEP-97
Sample Location Description: RAW WATER

Sample Comments Description:

istid	Parameter	Value	Units	Qual	Rmks
	Nitrogen; total Kjeldahl	0.34	mg/L		
3369L1	Fluoride	0.08	mg/l		
	Nitrogen; nitrate+nitrite	0.2	mg/L	<T	
3370L1	Carbon; dissolved organic	5.4	mg/L		
	Carbon; dissolved inorganic	50.6	mg/l		
	Silicon; reactive silicate	6.00	mg/l		

TABLE i

OBJECTIVE: Find optimum PACl dosage

DATE: Sept. 24/97 SAMPLE VOLUME: 1 L RUN # 1

CHEMICAL DOSAGES (MG/L)

JAR	PACl	mL		LT35	mL							
1	20	2		0.5	0.5							
2	25	2.5		0.5	0.5							
3	30	3		0.5	0.5							
4	35	3.5		0.5	0.5							
5	40	4		0.5	0.5							
6	45	4.5		0.5	0.5							

OBSERVATIONS

1 -at beginning of ~~[illegible]~~ slow mix after 5 min. floc is poor in all jars.

2

- very poor floc - all runs abandoned.

3

-

4

5

6

CHEMICAL ANALYSIS

	SUPERNATANT				FILTRATE					
	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Aluminum	Iron
1										
2										
3										
4										
5										
6										
	FTU	TCU	Dimensionless	mg/L	FTU	TCU	Dimensionless	mg/L	mg/L	mg/L

COMMENTS

-run PACl together with LT35.

Slow Mix - began at 2:10

TABLE

OBJECTIVE: Find a polymer that will work with PACl

DATE:

SAMPLE VOLUME: 1 L

RUN # 2

CHEMICAL DOSAGES (MG/L)

				N	C	C	A	A	A		
JAR	PACl	mL		LT20	LT22	LT24	LT25	LT26	LT 27A		mL
1	35	3.5		0.5							.5
2					0.5						
3						0.5					
4							0.5				
5								0.5			
6	↓	↓							0.5		↓

OBSERVATIONS

1	good floc NOTE: all jars much better than LT35.
2	- floc in this jar is smaller than in 1, 3, 4, 5, 6 floc in 1, 3, 4, 5 similar.
3	good floc FLOC AFTER 20 min: #6 by a mile, then 1+3, then 2+4+5.
4	good floc SETTLING: #6 then 1+3 then 2+4+5.
5	good floc
6	- ~~large~~ strong floc; most excelleeeent! - could it be because it was the last one added with le - orange - brown colour (others are lighter in colour) - excellent settling.

flash
time?

CHEMICAL ANALYSIS

	SUPERNATANT				FILTRATE					
	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Aluminum	Iron
1	0.48	15			0.26				0.186	
2	0.34	10			0.28				0.182	
3	0.29	9			0.28				0.177	
4	0.27	10			0.40					
5	0.27	11			0.26					
6	0.18	7			0.17				0.154	
	FTU	TCU	Dimensionless	mg/L	FTU	TCU	Dimensionless	mg/L	mg/L	mg/L

I kno
fro
experi
that
won't
very
much

COMMENTS

The plant is currently dosing at 35 mg/L, so we will do the same and try 6 polys. After That we can use the best of the 6 polys' to find optimum PACl dosage.

slow mix start: 3:05

Settle start 3:25

MOEE STB WWOS TREATABILITY STUDIES

TABLE

OBJECTIVE: See below

DATE: Sept. 25 SAMPLE VOLUME: 1L RUN # 3

CHEMICAL DOSAGES (MG/L)

JAR	PACl	mL	LT27A	mL	LT35	mL
1	35	3.5	0.5	0.5	~~[illegible]~~	~~[illegible]~~
2	35	3.5			1.25	1.25
3						
4						
5						
6						

← extra mix-t
total o
poly ad

OBSERVATIONS

1 -again excellent floc with LT27. -flash mix time after poly addition has little effect.

2 -even with higher LT35 dosage, floc is CRAP!

3

4

5 -no Chem. analysis done - objective was achieved.

6

CHEMICAL ANALYSIS

SUPERNATANT / FILTRATE

	Supernatant Turbidity	Supernatant Colour	Supernatant pH	Supernatant Alkalinity	Filtrate Turbidity	Filtrate Colour	Filtrate pH	Filtrate Alkalinity	Filtrate Aluminum	Filtrate Iron
1										
2										
3										
4										
5										
6										
	FTU	TCU	Dimension-less	mg/L	FTU	TCU	Dimension-less	mg/L	mg/L	mg/L

COMMENTS

I wondered if great floc with LT27A in run #2 was due to it having the least amount of flash mix time - In this run I will give it an extra minute of flash mix. I also want to see if the fact that LT35 is a 40% soln. is responsible fo

poor performance - I will dose at $\frac{0.5\ mg/L}{40\%} = 1.25\ mg/L$ to see if there is an improvem

SLOW MIX START: 10:07

SED. START 10:27.

MOEE STB WWOS TREATABILITY STUDIES

TABLE

OBJECTIVE: Find optimum PACl dosage

DATE: Sept. 25/97 SAMPLE VOLUME: 1 L RUN # 4

CHEMICAL DOSAGES (MG/L)

JAR	PACl	mL	LT27A	mL
1	20	2	0.5	0.5
2	25	2.5	↓	↓
3	30	3	↓	↓
4	35	3.5	↓	↓
5	40	4	↓	↓
6	45	4.5	↓	↓

OBSERVATIONS

1 - less floc than others - some small interstitial floc but floc itself is larger + denser.

2 - more floc than #1

3 - more floc than #2

4 - same as 3

5 - ~~same as 3~~ floc slightly larger than 3,4.

6 - more floc than 3,4,5 but smaller in size.

SETTLING 1,2,5 3,4,6
best → worst
however it is good even in #6. in #6 (the worst) settling is complete in 1 minute.

CHEMICAL ANALYSIS

	SUPERNATANT				FILTRATE					
	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Aluminum	Iron
1	0.25	12							>.250	
2	0.20	10							>.250	
3	0.21	10							0.220	
4	0.18	8							0.175	
5	0.20	7							0.159	
6	0.18	5							0.138	
	FTU	TCU	Dimension-less	mg/L	FTU	TCU	Dimension-less	mg/L	mg/L	mg/L

COMMENTS

slow mix: start 10:43

settling start 11:03

* raw pH = 8.03

MOEE:

PAGE

Inconclusive, will have to do another run.

TABLE

OBJECTIVE: Find optimum PACl dosage.

DATE: SAMPLE VOLUME: RUN # 5

CHEMICAL DOSAGES (MG/L)

JAR	PACl	mL		LT27A	mL							
1	40	4		0.5	0.5							
2	45	4.5		|	|							
3	50	5		|	|							
4	55	5.5		|	|							
5	60	6		↓	↓							
6	65	6.5		√	√							

OBSERVATIONS

1 - floc the same in all jars - medium size - not as good as in previous run.

2

3 SETTLING: Same in all jars - good - done in 1 minute.

4

5

6

CHEMICAL ANALYSIS

	SUPERNATANT					FILTRATE					
	Turbidity	Colour	pH	Alkalinity		Turbidity	Colour	pH	Alkalinity	Aluminum	Iron
1	0.24	10						7.56		0.162	
2	0.16	11						–		0.154	
3	0.14	~~5~~ 7						7.85		0.134	
4	0.18	12						–		0.124	
5	0.14	5						7.84		0.113	
6	0.17	8						–		0.097	
	FTU	TCU	Dimension-less	mg/L		FTU	TCU	Dimension-less	mg/L	mg/L	mg/L

COMMENTS

SLOW MIX START 1:48.

NOTE: repeatability of Al results is very good.

TODAY'S RAW COLOR = 36 ACU
RAW pH = 8.37.

MOEE STB WWOS TREATABILITY STUDIES

TABLE

OBJECTIVE: Find optimum PACl dosage

DATE: Sept. 26/97 SAMPLE VOLUME: 1L RUN # 6

CHEMICAL DOSAGES (MG/L)

JAR	PACl	mL		LT27A	mL
1	55	5.5		0.5	0.5
2	60	6		│	│
3	65	6.5		│	│
4	70	7		│	│
5	75	7.5		│	│
6	80	8		↓	↓

OBSERVATIONS

1	-floc same in all jars - same as run 5
	-med. size floc
2	
3	SETTLING: all good; 3+4 a bit faster than others
	-virtually complete in 1 min.
4	
5	
6	

CHEMICAL ANALYSIS

	SUPERNATANT				FILTRATE					
	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Aluminum	Iron
1	0.12	~~8~~ 4					8.00		0.121	
2	0.11	4					7.90		0.108	
3	0.15	3					7.85		0.098	
4	0.11	3					7.88		0.087	
5	0.15	4					7.81		0.093	0.097 REPEAT
6	0.12	3					7.82		0.085	
	FTU	TCU	Dimensionless	mg/L	FTU	TCU	Dimensionless	mg/L	mg/L	mg/L

COMMENTS

It look as if the bottom has been reached for Al residual.
Optimum appears to be 70 mg/L.

slow mix start: 9:20

TABLE

OBJECTIVE: Find optimum AS dosage

DATE: SAMPLE VOLUME: RUN # 7

CHEMICAL DOSAGES (MG/L)

JAR	AS	mL	LT27a	mL
1	50	5	0.5	0.5
2	60	6	"	"
3	70	7	"	"
4	80	8	"	"
5	90	9	"	"
6	100	10	↓	↓

OBSERVATIONS

1 Floc is larger than in other jars: less of it too. medium-sized to large ragged, "sticky" floc produced.

2, 3 floc smaller than 1 and less dense

SETTLING: #1 fastest then 2, then 3, then 4, 5, 6.

4, 5, 6 this floc looks more sticky & ragged.

- all settled fairly quickly though.

CHEMICAL ANALYSIS

	SUPERNATANT				FILTRATE					
	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Aluminum	Iron
1	0.45	17					7.90		0.121	
2	0.38	14					7.81		0.102	
3	0.32	12					7.71		0.091	
4	0.29	15					7.66		0.078	
5	0.29	9					7.60		0.066	
6	0.36	9					7.53		0.072	
	FTU	TCU	Dimensionless	mg/L	FTU	TCU	Dimensionless	mg/L	mg/L	mg/L

COMMENTS

- it appears as if a minimum Al res. was encountered at 90 mg/L. This seems to be the optimum. Try AF in the next run at 50→100

slow mix start 1:58

TABLE

OBJECTIVE: Find optimum A7

DATE: SAMPLE VOLUME: 1L RUN # 8

CHEMICAL DOSAGES (MG/L)

JAR	A7	LL		CT27	LL
1	50	5		0.5	0.5
2	60	6			
3	70	7			
4	80	8			
5	90	9			
6	100	10		↓	↓

OBSERVATIONS

1 floc similar to previous run, med to large, + ragged + sticky

2 1->4 are more compact +larger than 5+6, but not a great difference.

3 -after 15 min. floc in 1-4 looks really good - large + strong
- 5+6 are smaller + ragged looking esp. #6.

4 - #5 is only slightly less quality than #4.

5 SETTLING: 1, then 3, then 2+4, then 5+6
-all settled in 1 min.

6

CHEMICAL ANALYSIS

SUPERNATANT / FILTRATE

	Supernatant Turbidity	Supernatant Colour	Supernatant pH	Supernatant Alkalinity	Filtrate Turbidity	Filtrate Colour	Filtrate pH	Filtrate Alkalinity	Filtrate Aluminum	Filtrate Iron
1	0.47	6					7.78		0.110	
2	0.33	4					7.74		0.092	
3	0.34	5					7.77		0.089	
4	0.31	5					7.70		0.084	
5	0.31	1					7.58		0.084	
6	0.34	2					7.49		0.074	
	FTU	TCU	Dimensionless	mg/L	FTU	TCU	Dimensionless	mg/L	mg/L	mg/L

COMMENTS

SLOW MIX START 4:44

~~MIXIN~~ SETTLING START 5 04.

TABLE: Warkworth DATE: Sept. 30/97.

TREATABILITY STUDY OBJECTIVE					
New batch of water collected					
RAW WATER SOURCE : Burnley Creek					
JAR TEST CONDITIONS			**RAW WATER QUALITY**		
TREATMENT MODE:			TEMPERATURE	14°	C
FLASH MIX :	TIME -	MIN	ALKALINITY	196	MG/L
	SPEED -	RPM	PH	8.00	**
FLOCCULATION:	TIME -	MIN	TURBIDITY	10.5	FTU
	SPEED -	RPM	COLOUR	80 App 50 True	TCU
SEDIMENTAION:	TIME -	MIN			
FILTER MEDIA:					

CHLORINE DEMAND					**TTHM FORMATION POTENTIAL**			
JAR #	CL2 MG/L	FREE MG/L	TOTAL MG/L		JAR #	CL2 MG/L	TTHM UG/L	
1								
2								
3								
4								
5								
6					RESULTS OF A 7 DAY FORMATION POTENTIAL TEST			
	mg/L	mg/L	mg/L		TTHM:TOTAL TRIHALOMETHANES			

ADDITIONAL COMMENTS:

Ontario Ministry of Environment & Energy
Central Laboratory - 125 Resources Road
FINAL REPORT (manager)
Oct 24, 1997 11:46 am
Login: C46983

RAW WATER QUALITY FOR 2nd SERIES OF JAR TESTS.

FINAL ANALYTICAL RESULTS

Field ID: WK-JT-R2
Sample ID: C46983-0001
MOEE*LIMS ID: 97WD40-00009
Station ID:
Collect Date: 30-SEP-97
Sample Location Description: WARKWORTH RAW JAR TESTS

Sample Comments Description:

Testid	Parameter	Value	Units	Qual	Rmks
3016L1	Chloride	6.2	mg/L		
3172L1	Sulphate	18.0	mg/L		
3188L4	Solids; dissolved	252.	mg/L		CRO
3217L1	Calcium	67.6	mg/L		
	Magnesium	9.90	mg/L		
	Sodium	5.0	mg/L		
	Potassium	1.35	mg/L		
	Hardness	210.	mg/L		
3218L1	Conductivity	388.	uS/cm		
	pH	8.20	none		
	Alkalinity; total fixed endpt	196.	mg/L CaCO		
3219L1	Colour; true	44.6	TCU		
3274L1	Langeliers index calculation	0.95	none		
	Saturation pH Estimated	7.25	none		
3311L1	Turbidity	5.50	FTU		
3364L1	Nitrogen; ammonia+ammonium	0.016	mg/L		
	Nitrogen; nitrite	0.003	mg/L	<T	
	Nitrogen; nitrate+nitrite	0.130	mg/L		
	Phosphorus; phosphate	0.0155	mg/L		
3367L1	Phosphorus; total	0.050	mg/L		
	Nitrogen; total Kjeldahl	0.62	mg/L		

Field ID: WK-JT-R2
Sample ID: C46983-0001
MOEE*LIMS ID: 97WD40-00009
Station ID:
Collect Date: 30-SEP-97
Sample Location Description: WARKWORTH RAW JAR TESTS

Sample Comments Description:

istid	Parameter	Value	Units	Qual	Rmks
3369L1	Fluoride	0.07	mg/L		
	Nitrogen; nitrate+nitrite	.1	mg/L	<=W	
3370L1	Carbon; dissolved organic	8.3	mg/L		
	Carbon; dissolved inorganic	44.4	mg/L		
	Silicon; reactive silicate	5.52	mg/L		

MOEE STB WWOS TREATABILITY STUDIES

TABLE

OBJECTIVE: Find optimum PACl dosage

DATE: Sept. 30/97. SAMPLE VOLUME: 1 L RUN # 1

CHEMICAL DOSAGES (MG/L)

JAR	PACl	mL	LT7	mL
1	60	6	0.5	0.5
2	70	7	|	
3	80	8		
4	90	9		
5	100	10		
6	110	11	↓	↓

OBSERVATIONS

1	overall floc appearance is
	same as that formed in 1st
2	batch of water. Just more of it.
3	jars 1, 2 do not have as much
	floc as others, esp. #1.
4	SETTLING: 1, 2 settled a bit faster than rest.
	In all jars, almost all are nearly all settled after 1 minute.
5	
6	

CHEMICAL ANALYSIS

	SUPERNATANT				FILTRATE					
	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Aluminum	Iron
1	0.20	13					7.87		0.086	
2	0.15	10					7.81		0.079	
3	0.13	8					7.71		0.077	
4	0.14	6					7.68		0.068	
5	0.14	6					7.63		0.054	
6	0.15	7					7.59		0.047	
	FTU	TCU	Dimension-less	mg/L	FTU	TCU	Dimension-less	mg/L	mg/L	mg/L

COMMENTS

SLOW MIX BEGIN: 12:50

MOEE STB WWOS TREATABILITY STUDIES

TABLE

OBJECTIVE: Find optimum A7 dosage

DATE: Oct. 1/97 SAMPLE VOLUME: RUN # 2

CHEMICAL DOSAGES (MG/L)

JAR	A7	mL		T27	mL						
1	70	7		0.5	0.5						
2	80	8									
3	90	9									
4	100	10									
5	110	11									
6	120	12		√	√						

OBSERVATIONS

1 floc is larger in jars 1,2,4 ; smaller in others. (1,2 better than 4)

2 -overall floc is medium size + somewhat ragged, more compact than in 1,2,4

3 -floc in jars 4 seems heavier than others - some settles out during slow mix.

4

SETTLING: jar 2 settled first

5 then 4

then 6

6 then 3+5

CHEMICAL ANALYSIS

	SUPERNATANT				FILTRATE					
	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Aluminum	Iron
1	0.36	13					7.59		0.097	
2	0.36	12					7.44		0.076	
3	0.27	9					7.34		0.097	
4	0.35	10					7.29		0.072	
5	0.28	8					7.20		0.084	
6	0.35	8					7.10		0.074	
	FTU	TCU	Dimension-less	mg/L	FTU	TCU	Dimension-less	mg/L	mg/L	mg/L

* outlier
see obser
re floc.

COMMENTS

RAW TODAY: Apparent Colour = 77
pH = 7.92

SLOW MIX BEGIN: 10:52

TABLE

OBJECTIVE: Confirming PACl + Clarion A7 Optimums.

DATE: Oct. 1/97 SAMPLE VOLUME: RUN # 3

CHEMICAL DOSAGES (MG/L)

JAR	PACl	mL	A7	mL	LT27	mL
1	50	5	–	–	0.5	0.5
2	90	9	–	–	↓	↓
3	120	12	–	–	↓	↓
4	–	–	60	6	↓	↓
5	–	–	100	10	↓	↓
6	–	–	140	14	↓	↓

OBSERVATIONS

1 *-it seems that for either coagulant, the best floc quality (jars 1+4) is when underdosing occurs. At high dosages, the floc is less compact + more ragged. This *

* remember this observation

2 * pattern has been seen in previous runs. Floc in jar 4 is really awesome.

3 In jar 4-6, there is a pronounced gradation in floc quality from great (4) -> good (5) -> fair to poor (6)

4 In jars 1-3; there is less of a gradation; 1 is better than 2 which is same as 3.

5 Jars 2+3 are better than 6. Jar 5 is better than 2+3 . Jars 1+5 are similar.

only fair

6 SETTLING: first 4, then 5, then 1, the 2,3,6

CHEMICAL ANALYSIS

	SUPERNATANT				FILTRATE					
	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Aluminum	Iron
1	0.25	15					7.84		0.110	
2	0.17	8					7.64		0.063	
3	0.18	14					7.50		0.043	
4	0.47	17					7.52		0.116	
5	0.36	14					7.31		0.072	
6	0.35	11					7.07		0.094	
	FTU	TCU	Dimensionless	mg/L	FTU	TCU	Dimensionless	mg/L	mg/L	mg/L

COMMENTS

Slow Mix Begin - 1:38 * don't get it!

MOEE STB WWOS TREATABILITY STUDIES

TABLE

OBJECTIVE: Find optimum A10 dosage.

DATE: OCT. 3/97　　SAMPLE VOLUME: 1L　　RUN # 4

CHEMICAL DOSAGES (MG/L)

JAR	A10	mL		LT27	mL						
1	50	5		0.5	0.5						
2	70	7		|	|						
3	90	9		|	|						
4	110	11		|							
5	130	13			|						
6	150	15		↓	↓						

OBSERVATIONS

1 - floc in #2 is largest + most compact

- next best is #1

2 - next best are 3,4 - a bit smaller than #2 but more numerous.

- #5,6 have a poor looking floc - very ~~fine~~ small but lots of it

3

- the same I suspect is repeating itself, that is the best floc occurs

4 when UNDERdosing alum - we'll see whether analyses bear this out.

5 SETTLING: 1 is fastest, then 2, then 3,4 -> 5,6 are slow, settling visually complete in >15 minutes

6

CHEMICAL ANALYSIS

	SUPERNATANT				FILTRATE					
	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Aluminum	Iron
1	0.53	22	-	-			7.68	-	0.159	-
2	0.33	12	-	-			7.47	-	0.068	-
3	0.33	11	-	-			7.29	-	0.083	-
4	0.28	8	-	-			7.07	-	0.076	-
5	0.44	9	-	-			6.97	-	0.111	-
6	0.45	10	-	-			6.76	-	0.130	-
	FTU	TCU	Dimension-less	mg/L	FTU	TCU	Dimension-less	mg/L	mg/L	mg/L

COMMENTS

TODAY RAW APP. COLOUR = 84

" " pH = 8.20

slow mix start 10:18

536-5435

MOEE STB WWOS TREATABILITY STUDIES

TABLE

OBJECTIVE: Find optimum PACl dosage

DATE: Oct. 3/97.

SAMPLE VOLUME:

RUN # 5

CHEMICAL DOSAGES (MG/L)

JAR	PACl	mL		LT27	mL
1	50	5		0.5	0.5
2	70	7		│	│
3	90	9		│	│
4	110	11		│	│
5	130	13		│	│
6	150	15		↓	↓

OBSERVATIONS

1 - the same pattern was observed; the best floc appears to be in jars that are underdosed.

2 - the best floc is in #1, the floc in jars 4, 5, 6 is fluffier + a bit less dense, but there appears to be more of it.

3

4

5

6

CHEMICAL ANALYSIS

	SUPERNATANT					FILTRATE					
	Turbidity	Colour	pH	Alkalinity		Turbidity	Colour	pH	Alkalinity	Aluminum	Iron
1	0.23	11	–	–		–	–	7.83	–	0.134	–
2	0.19	6	–	–		–	–	7.74	–	0.089	–
3	0.14	5	–	–		–	–	7.63	–	0.070	–
4	0.16	4	–	–		–	–	7.52	–	0.051	–
5	0.18	3	–	–		–	–	7.46	–	0.043	–
6	0.16	2	–	–		–	–	7.39	–	0.036	–
	FTU	TCU	Dimension-less	mg/L		FTU	TCU	Dimension-less	mg/L	mg/L	mg/L

COMMENTS

- still can't reach optimum based on Al residual; BUT quality would be quite good at 90 mg/L, and floc quality would be a little better.

Slow mix start 1:04

PAGE

MOEE:

MOEE STB WWOS TREATABILITY STUDIES to ≈ ~~6.5~~ → actually 7.0.-7.2

TABLE

OBJECTIVE: After pH adj. → find optim PACl

DATE: Oct. 6/97. SAMPLE VOLUME: 1L RUN # 6

CHEMICAL DOSAGES (MG/L)

JAR	H_2SO_4	mL		PACl	mL		LT27	mL				
1		0.02 (2 drops)		40	4		0.5	0.5				
2				60	6							
3				80	8							
4				100	10							
5				120	12							
6		↓		140	14		↓	↓				

OBSERVATIONS

1 again, the same gradation in floc Quality is observed from #1 (likely under-dosed + best) to #6 (likely overdosed + worst.)

2

- the best floc is in 1,2,3. } (the gradation from 1-6 is quite even.) (in terms of floc quality + amount of floc

3

- the most floc is in 4,5,6.

4

SETTLING: #1 is best then 2 / then 3+4 / then 5+6.

5 good fair

6

CHEMICAL ANALYSIS

	SUPERNATANT					FILTRATE						
	Turbidity	Colour	pH	Alkalinity		Turbidity	Colour	pH	Alkalinity	Aluminum	Iron	
1	0.30	15						7.34		0.044		
2	0.17	16						7.36		0.037		
3	0.16	10						7.18		0.035		
4	0.14	8						7.16		0.027		
5	0.13	7						7.16		~~0.022~~	0.027	
6	0.14	5						7.02		0.023		
	FTU	TCU	Dimension-less	mg/L		FTU	TCU	Dimension-less	mg/L	mg/L	mg/L	

COMMENTS

TODAY'S RAW APP. COLOUR = 89

RAW pH = 8.41

slow mix start 1:38

Certificate of Approval (1992) and Amendment to the Certificate of Approval

Appendix C

Ministry of the Environment
Ministère de l'Environnement
Ontario

AMENDMENT TO CERTIFICATE OF APPROVAL
WATER
NUMBER 7-1535-91-926
Page 1 of 2

NOTICE

Township of Percy
P.O. Box 129
40 Main Street
Warkworth, Ontario
K0K 3K0

You are hereby notified that the approval for the upgrading and expansion of the existing water treatment plant serving the Police Village of Warkworth located on Lot 14, Concession 3 in the Township of Percy, issued under Certificate of Approval No. 7-1535-91-926 dated February 20, 1992, is hereby amended to approve the following modifications to the chemical feed (chlorination) system:

Pre-chlorination

Discontinue the practice of pre-chlorination of the raw water at the raw water well and to retain the chemical feed facilities for periodic 'shock' chlorination when required.

Post-chlorination

Installation of chemical feed facilities for post-chlorination, consisting of two (2) diaphragm type chemical metering pumps, one (1) chemical storage day tank, associated piping and appurtenances to inject sodium hypochlorite solution into each filter effluent pipe,

all in accordance with the design brief dated November 1997 prepared by RAL Engineering Ltd.

REASON

The reason for this amendment is to approve modifications to the existing chlorination system at the water treatment plant in order to control the level of trihalomethanes (THMs) in the treated water and distribution system. A design brief (dated November 1997 and prepared by RAL Engineering Ltd.) for the proposed modifications, which are supported by the Ministry's Standards Development Branch, was received and found to be satisfactory.

This Notice shall constitute part of the approval issued under Certificate of Approval No. 7-1535-91-926 dated February 20, 1992.

In accordance with Section 100 of the Ontario Water Resources Act, R.S.O. 1990, Chapter 0.40, as amended, you may by written notice served upon me and the Environmental Appeal Board within 15 days after receipt of this Notice, require a hearing by the Board. Section 101 of the Ontario Water Resources Act, provides that the Notice requiring the hearing shall state:

1. The portions of the approval or each term or condition in the approval in respect of which the hearing is required, and;
2. The grounds on which you intend to rely at the hearing in relation to each portion appealed.

The Notice should also include:

3. The name of the appellant;
4. The address of the appellant;
5. The Certificate of Approval number;
6. The date of the Certificate of Approval;
7. The name of the Director;
8. The municipality within which the water works are located;

And the Notice should be signed and dated by the appellant.

This Notice must be served upon:

The Secretary,
Environmental Appeal Board,
2300 Yonge Street, 12th Floor,
P.O. Box 2382,
Toronto, Ontario.
M4P 1E4

AND

The Director,
Section 52, *Ontario Water Resources Act*,
Ministry of the Environment,
250 Davisville Avenue, 3rd Floor,
Toronto, Ontario.
M4S 1H2

The above noted water works are approved under Section 52 of the Ontario Water Resources Act.

DATED AT TORONTO this 26th *day of* January, 1998.

Jan 27/98

M. Dhalla, P.Eng.,
Director,
Section 52,
Ontario Water Resources Act.

HV/ba

Attn: -Ms R. Colquhoun, Clerk, Township of Percy
cc: -District Manager, MOE Peterborough District Office
-RAL Engineering Ltd.
-Mr. Matt Uza, Standards Development Branch, MOE

TSH 52-20036

TO:

Township of Percy
Box 129
40 Main Street
Warkworth, Ontario
K0K 3K0

has applied in accordance with Section 23 of the Ontario Water Resources Act for approval of:

upgrading and expansion of the existing surface water, treatment and distribution system serving the Police Village of Warkworth and located on Lot 14, Concession 3 in the Township of Percy to be rated at gross maximum daily production of 1232 m^3/d with a design peak hour distribution system supply rate of 1851 m^3/d and a design fire flow of 64 L/s for two hours, where the peak hour flow is provided by the high lift pumps from the in-plant storage reservoir and the fire flow by the existing 506 m^3 capacity elevated (top-of-hill ground level) reservoir, to be implemented as follows:

- removal of the existing low lift pump (direct suction from the existing 250 mm diameter Mill Creek gravity intake pipe) from the existing treatment plant building , and extension of the intake pipe to the new raw water well described below (the existing screens in a manhole on the intake pipe remain in operation);

- construction of an extension to the existing treatment plant building to house a new package water treatment plant, chemical application facilities and a stand-by power generation set described below;

- removal of the existing gravity sand filter and chemical application facility from the existing treatment plant building, and construction of additional internal structures to utilize the space for office, laboratory, chemical storage and sludge pumping facilities;

- construction of a 31.6 m^3 capacity raw water well in the under-structure of the plant building extension, including installation of two(2) (one duty, one stand-by) new low lift solids handling submersible pumps, each having a capacity of 14.3 L/s at a TDH of 7.8 metres, controlled by the water level in the treated water reservoir described below;

- installation of an in-line static mixer in the low lift pump discharge pipe feeding the flocculation tanks in the package water treatment plant described below;

- installation of a prefabricated package water treatment plant in the above-described plant building extension, rated at 1232 m^3/d, and consisting of the following:

    - a three-tank-in-series flocculation chamber equipped with low speed vertical paddle wheel flocculators, having a minimum total hydraulic detention time of 30 minutes,

- an inclined tube settler type up-flow **sedimentation chamber** having a total surface area of 18.2 m², with overflow into two effluent launder troughs feeding the filters described below, and a timed automatic gravity sludge discharge into the spent backwash water surge tanks described below,

- two (2) parallel gravity **dual media rapid sand filters**, each having a filtration surface area of 3.4 m², rated at 7.5 m/hr, discharging by gravity into the in-ground treated water reservoir described below, with a backwash system serviced by the backwash pump installed in the treated water reservoir, and a spent backwash water collection system discharging into the spent backwash water surge tanks described below,

- construction of a 490 m³ capacity **in-ground treated water reservoir** in the under-structure of the plant building extension, consisting of four(4) cells with valved interconnections, equipped with three(3) (two duty, one stand-by) **high lift vertical turbine pumps**, each rated at 10.8 L/s at a TDH of 46.0 m, with a common header connected to the existing distribution feeder watermain at the plant site, and one(1) filter **backwash vertical turbine pump**, rated at 47.0 L/s at a TDH of 15.0 m;

- installation of the following chemical application systems in the plant building extension:

  - **coagulant** system, consisting of a 15 m³ capacity liquid coagulant storage tank with a remote fill line, two(2) (one duty, one stand-by) diaphragm type chemical metering pumps, and a feed line to a diffuser installed in the low lift pump discharge pipe up-stream of the in-line static mixer mentioned above,

  - **polymer** (coagulant aid) system, consisting of an integrated equipment package for automatic metering, diluting, activating and feeding of liquid polymer, with a suction line directly to a concentrated liquid polymer shipping drum, and a feed line to the diffusers installed in the low lift pump discharge pipe up-stream (three locations) and down-stream (one location) of the in-line static mixer mentioned above,

  - **sodium hypochlorite** (colour removal and disinfection) system consisting of two(2) (one duty, one stand-by) diaphragm type chemical metering pre-chlorination pumps controlled by the operation of the low lift pumps, with a feed line to a chlorine diffuser installed at the inlet of the intake pipe to the raw water well; two (2) (one duty, one stand-by) diaphragm type chemical metering post-chlorination pumps controlled by the operation of the high lift pumps and paced with the high lift discharge flow meter with feed lines to the chlorine diffusers installed in the treated water reservoir (two) and in the high lift pump header (one); and a continuous chlorine residual analyzer with a sampling line tapping the distribution feeder watermain 30 metres away from the plant;

- construction of a 24 m^3 capacity **spent backwash water surge tank** in the under-structure of the plant building extension, including installation of one(1) **submersible wastewater pump**, rated at 3.7 L/s at a TDH of 5.6 m, discharging into the sludge holding decant tank described below;

- conversion of the existing 25 m^3 capacity clear well into a second **spent backwash water surge tank**, including removal of the existing dry-well high lift pump and installation of one(1) **submersible wastewater pump**, rated at 3.7 L/s at a TDH of 5.6 m, discharging into the sludge holding backwash decanting tank described below;

- conversion of the existing 54 m^3 combined capacity flocculation and sedimentation tanks into a **sludge holding backwash decanting tank**, including installation of a **supernatant return pipe system** with outlet ports at various elevations, discharging into the raw water well, and two (2) (one duty, one stand-by) **sludge transfer dry well horizontal pumps**, each rated at 23 L/s at a TDH of 6.3 m, with a discharge pipe at the plant's tanker truck loading platform for off-site disposal;

- installation of a 58 Kw stand-by Diesel engine power generator set and an oil storage tank in the plant building extension;

- all associated mechanical (including ventilation) and electrical installations, instrumentation, and control equipment;

all in accordance with the information contained in the documents listed in the attached Schedule "A", at a total estimated cost, including engineering and contingencies, of ONE MILLION, ONE HUNDRED AND FORTY THOUSAND DOLLARS ($2,140,000.00).

You are hereby notified that this approval is issued to you subject to the following terms an conditions outlined below:

TERMS AND CONDITIONS

General

1. For the purpose of this Certificate of Approval:

   (a) "the Director" means any Ministry employee within the Environmenta Planning and Prevention Division of the Ministry appointed by th Minister pursuant to section 4 of the Ontario Water Resources Ac as a Director for the purposes of Sections 6, 23, 24, 25, 26 and 2 of said Act;

   (b) "the Regional Director" means the Regional Director of the Centra Region of the Ministry of the Environment;

(c) "the District Officer" means the District Officer of the Peterborough District Office of the Ministry of the Environment's Central Region;

(d) "the Owner" means the Corporation of the Township of Percy, and includes its successors and assignees such as the Operating Authority;

(e) "the works" means the facility described in the Owner's application, the Certificate and in the supporting documentation referred to herein, to the extent approved by this Certificate;

(f) "the water supply and treatment system" means the works and auxiliaries for collection, treatment, storage and distribution of water from the source of supply to the free flowing outlets of the ultimate consumers';

(g) "Maximum Acceptable Concentration" means a limit applied to concentrations of substances in the drinking water above which there are known or suspected adverse health effects;

(h) "quarterly sampling" means sampling conducted on any such day within each consecutive three-month period that the time interval between consecutive quarterly sampling events is not less than 45 days.

2. (1) The requirements of this Certificate of Approval are imposed pursuant to Section 23 of the Ontario Water Resources Act. The issuance of this Certificate in no way abrogates the Owner's legal obligations to take all reasonable steps to avoid violating other applicable provisions of this legislation and other legislations and regulations.

(2) Pursuant to subsection (2), prior to construction of the works, the Owner shall obtain an approval (air) under the Environmental Protection Act for installation of the proposed stand-by Diesel engine power generator.

3. (1) The requirements of this Certificate are severable. If any requirement of this Certificate, or the application of any requirement of this Certificate to any circumstances, is held invalid, the application of such requirement to other circumstances and the remainder of this Certificate shall not be affected thereby.

(2) In all matters requiring the interpretation and implementation of this Certificate, the conditions of the Certificate shall take precedence, followed in descending order by the Owner's application and the documentation, referred to in this Certificate, which is submitted in support of the application.

4. The Owner must ensure compliance with all the terms and conditions of this Certificate. Non-compliance constitutes a violation of the Ontario Water Resources Act and is grounds for enforcement.

5. The Owner shall, forthwith upon the request of the Director, Regional Director and District Officer, or any of them, furnish any information requested concerning compliance with this Certificate including any records required to be kept by this Certificate.

6. The Owner shall notify the Regional Director in writing of any of the following changes within 30 days of the change occurring:

   (a) change of Owner or operating authority or both;
   (b) change of address or address of the new Owner.

7. (1) The Owner shall prepare and make available for inspection by Ministry personnel upon request, a complete set of drawings within one (1) year of substantial completion of the water works which drawings shall show the water works as constructed at that time.

   (2) A complete set of the "as constructed" drawings, incorporating any amendments made from time to time, shall be kept by the Owner at the administration building of the water works as long as the water works is kept in operation.

Commencement of Construction

8. The Owner shall not commence construction of the works or allow its commencement until the Owner has obtained from the Regional Director a Permit to Take Water for the proposed increase in water taking.

Operation and Maintenance

9. (1) The Owner shall endeavour to take all necessary steps, within his authority, to ensure protection of the source of water supply from contamination.

   (2) Subsequent to construction of, or repairs to the works, and prior to utilization of the works for the supply of potable water, the Owner shall ensure that the works have been adequately disinfected.

   (3) The Owner shall ensure that, at all times, the water works and related equipment and appurtenances which are installed or used to achieve compliance with this Certificate are properly operated and maintained. Proper operation and maintenance includes effective performance, adequate funding, adequate operator staffing and training, adequate laboratory and process controls, and the use of process chemicals and other substances that come in contact with water being treated, that are suitable for the process, compatible with each other and appropriate for drinking water.

(4) Further to subsection (3), the Owner shall ensure that al chemicals used in the treatment process meet the American Wate Works Association standards for drinking water treatment chemicals meet the National Sanitation Foundation standard 60 and are foo grade chemicals.

(5) The Owner shall ensure that, prior to commissioning of the wate works, contingency plans and procedures are established an adequate equipment and material are available for dealing wit emergencies, spills, upset conditions and equipment breakdowns i the water works.

(6) The Owner shall establish notification procedures to be used t contact the Regional Director and other relevant authorities in th case of an emergency situation.

(7) The Owner shall prepare a manual of contingency plans ar procedures and notification procedures, referred to in subsectior (5) and (6), and keep it up to date and shall, upon request, mak the manual available for inspection by Ministry personnel ar shall, upon request, furnish a copy of the manual to the Ministry

(8) The Owner shall prepare an operations and maintenance manual ar keep it up to date and shall, upon request, make the manua available for inspection by Ministry personnel and shall, upc request, furnish a copy of the manual to the Ministry.

(9) The Owner shall establish procedures for receiving and respondi to complaints, including a system for recording steps taken determine the cause of each complaint and measures taken alleviate the cause and prevent its recurrence.

(10) The Owner shall establish security procedures and where necessar construct and/or install appropriate access restricting faciliti and security systems to prevent unauthorized access to the wat works.

Performance

10. The Owner shall design, construct and, subject to Condition No. 1 operate the entire water supply and treatment system in such a manne and with such facilities that water supplied to the consumers servic by the system satisfies the water quality objectives, guidelines a requirements as set out in the publication entitled "Ontario Drinki Water Objectives" 1983, as amended from time to time by more recent published editions.

11. (1) The water treatment plant has been designed and approved to tre water at a total maximum flow rate of 1232 m^3/d.

11. (2) For the purpose of this Certificate and subsection 66(3) of the Ontario Water Resources Act, the introduction of flows into the water treatment plant in excess of the maximum flow rate shown in subsection (1) above is not approved under this Certificate except:

(i) where necessary, to meet an unusual water demand for fighting a conflagration; or

(ii) where necessary for the purpose of maintenance of the water works, essential to their efficient operation, provided that the quality requirements for the treated water will be satisfied.

(3) The Owner shall record the time and duration of each event of flow rate in excess of that specified in subsection (1) of this Condition along with the reasons for it.

12. (1) The Owner shall construct and operate the disinfection system in such a manner and with such facilities that a minimum of 0.5 mg/L of total chlorine residual in the treated water after minimum 15 minutes contact time, and before the first consumer, is maintained at all times.

(2) The Owner shall notify the District Officer and the Medical Officer of Health forthwith in the event that unchlorinated water is directed to the distribution system.

13. (1) The Owner shall use best efforts to construct and operate the backwash treatment facilities in such a manner that the concentration of suspended solids in the backwash wastewater settling tank supernatant discharged into the treatment plant's raw water wet well is minimized.

(2) The Owner shall ensure that, periodically, the entire contents of the backwash wastewater settling tanks is discharged to waste without decanting any supernatant.

Monitoring and Reporting

14. (1) The Owner shall install, maintain and operate a sufficient number of flow measuring devices, calibrated at regular intervals not exceeding one year to ensure their accuracy to within plus or minus 5% of the actual flow rate for the entire design range of the devices, in order to measure:

(i) the flow rate of water being conveyed to and through the water treatment plant (raw water);

(ii) the daily quantity of treated water supplied to the distribution system.

14. (2) The data generated in accordance with subsection (1) above shall b deemed to be conclusive of the minimum flow rates for the purposes of determining compliance with and enforcement of this Certificate

(3) The Owner shall install, maintain and operate continuous wate quality analyzers and indicators with alarm systems, calibrated a regular intervals not exceeding three months, in order to measure:

(i) free chlorine residual in treated water;

(ii) filtered water turbidity in common filter discharge line.

15. The Owner shall ensure that the following monitoring program is carrie out:

(a) Sampling locations shall be established to the satisfaction of th District Officer prior to commencement of operation of the works. Sampling locations may only be changed or abandoned and ne locations added following commencement or operations if, in th opinion of the District Officer, it is necessary to do so to ensur representative samples are being collected.

(b) Samples of raw water and treated water shall be collected an analyzed for at least the following parameters at the indicate frequency:

RAW WATER

Quarterly	Weekly
Alkalinity	Total Coliform
Hardness	Fecal Coliform
Calcium	pH
Sodium	Turbidity
Iron	Colour
Copper	
Lead	
Zinc	
Arsenic	
Aluminum	
Manganese	
Conductivity	
Chloride	
Sulphate	
Ammonia + Ammonium (N)	
Total Kjeldahl Nitrogen	
Nitrite	
Nitrate	
Dissolved Organic Carbon	
Phenols	

In addition to the above routine sampling program, on-site testing should be performed and results recorded, at the minimum frequency of once a day, for the following water parameters:

- pH, Colour, Turbidity, Temperature

TREATED WATER

Quarterly

Alkalinity
Hardness
Calcium
Sodium
Iron
Copper
Lead
Zinc
Arsenic
Aluminum
Manganese
Conductivity
Chloride
Sulphate
Ammonia + Ammonium (N)
Total Kjeldahl Nitrogen
Nitrite
Nitrate
Dissolved Organic Carbon
Total Trihalomethanes

Weekly

Total Coliform
Fecal Coliform
Standard Plate Count
pH
Turbidity
Colour

In addition to the above routine sampling program, on-site testing should be performed and results recorded, at the minimum frequency of twice a day, for the following treated water parameters:

- pH, Colour, Turbidity, Temperature, Free Chlorine Residual, Total Chlorine Residual.

DISTRIBUTION SYSTEM

Quarterly

Alkalinity
Hardness
Calcium
Sodium
Iron
Copper
Lead
Zinc

Weekly

Total Coliform
Fecal Coliform
Standard Plate Count
Colour

DISTRIBUTION SYSTEM (Continued)

Quarterly	Weekly
Arsenic	
Aluminum	
Manganese	
Conductivity	
Chloride	
Sulphate	
Ammonia + Ammonium (N)	
Total Kjeldahl Nitrogen	
Nitrite	
Nitrate	
Dissolved Organic Carbon	
Total Trihalomethanes	

NOTE: The minimum number of bacteriological samples to be collected from different locations of sampling points shall be as outlined in the "Ontario Drinking Water Objectives" 1983, as amended from time to time by more recently published editions.

(c) Subject to subsection (f) of this Condition, once a year, the raw water and treated water samples shall be collected and analyzed for parameters as listed in Table 1 and Table 2 of the "Ontario Drinking Water Objectives" 1983, as amended from time to time by more recently published editions.

(d) The sampling and analyses required by subsections (b) and (c) of this Condition shall be performed in accordance with the "Guide to the Collection and Submission of Samples for Laboratory Analysis", Ministry of the Environment, 1985, and the "Handbook of Analytical Methods for Environmental Samples", Ministry of the Environment, 1983, or as described in Standard Methods for the Examination of Water and Wastewater, 16th Edition, 1985, as amended from time to time by more recently published editions.

(e) The Owner shall submit the analytical results obtained pursuant to this Condition to the District Officer within thirty (30) days of collection of the samples or within such longer period of time as the District Officer may agree.

(f) Following review of any of the analytical results or any of the reports required by Condition No. 16 of this Certificate, the Regional Director may alter the frequencies and locations of sampling and parameters for analysis required by this condition if he/she considers it necessary for proper assessment of the quality of supplied water or if he/she is requested to do so by the Owner and considers it acceptable by the evidence of information submitted in support of the request.

(g) If the Owner monitors any of the parameters required by subsection (b) of this Condition, at locations designated for this purpose by the District Officer and in accordance with subsection (d), more frequently than it is required by this Condition, the analytical results of all such samples, both required and additional, shall be included in reporting of the values required by this Certificate, and the increased frequency, or all dates of sampling, shall also be specified in the reports.

(i) Notwithstanding subsection (e) of this condition, the Owner shall notify the District Officer and the Medical Officer of Health forthwith if any analytical result exceeds any Maximum Acceptable Concentration of a health-related parameter, or shows unsafe bacteriological water quality, or shows confirmed bacteriological water quality, as defined in the publication entitled "Ontario Drinking Water Objectives" 1983, as amended from time to time by more recently published editions.

16. The Owner shall prepare and submit a performance report to the District Officer on an annual basis. The first such report shall cover the period from the commencement of operation of the water supply and distribution system to the end of the calendar year and shall be submitted within ninety (90) days following such reporting period. Each subsequent report shall be submitted within ninety (90) days of the completion of the calendar year being reported upon. The reports shall contain, but need not be limited to, the following information in a format acceptable to the District Officer:

(a) a summary and discussion of the quantity of water supplied during the reporting period compared to the design values for the population serviced, including peak flow rates, maximum daily and monthly average flows;

(b) a summary and interpretation of analytical results obtained in accordance with Condition No. 15 of this Certificate of Approval;

(c) a tabulation and description of any emergency or upset conditions which occurred during the period being reported upon;

(d) a summary of the chemicals used in treatment processes with special reference to any abnormal usages.

You are hereby notified that Certificate of Approval No. 7-1535-91-926 has been issued to you subject to the terms and conditions outlined therein.

The reasons for the imposition of these terms and conditions are as follows:

1. Condition No. 1 is included to define terms used in this Certificate of Approval.

2. Condition No. 2 is included to emphasize that the issuance of the Certificate does not diminish any other statutory and regulatory obligation to which the Owner is subject in the construction, maintenance and operation of the works.

3. Condition No. 3 is included to clarify how the Certificate is to be judicially interpreted and specifically, to clarify that the requirements of the Certificate are severable and that they prevail over supporting documentation.

4. Condition No. 4 is included to emphasize that the Owner is under a statutory obligation to ensure compliance with the Certificate.

5. Condition No. 5 is included to ensure that Ministry personnel, when acting in the course of their duties, will be given unobstructed access to the facilities, information and records related to the works which are the subject of this Certificate, to enable the Ministry to b assured of the Owner's compliance with the terms and conditions of thi Certificate.

6. Conditions Nos. 6 and 7 are included to ensure that the Ministry record can be kept accurate and current with respect to approved works and t ensure that subsequent owners of the works are made aware of th Certificate and continue to operate the works in compliance with it.

7. Condition No. 8 is included due to the provisional nature of thi approval being subject to obtaining by the Owner a permit for th proposed increase in water taking from the Mill Creek.

8. Condition Nos. 9 is included to ensure that the works will be operated maintained, funded, staffed and equipped in a manner enabling complianc with the terms and conditions of this Certificate and that the Owner ca deal with contingency and/or emergency situations.

9. Conditions Nos. 10 and 12 are included to ensure that the water qualit delivered by the treatment plant satisfies the current "Ontario Drinki Water Objectives" in order to protect public health and to ensure tha the water is aesthetically acceptable.

10. Condition No. 11 is included to ensure that the peak flow rate of wat through the works is within the approved treatment capacity of th works.

11. Condition No. 13 is imposed to prevent unnecessary solids load on th filters and shortening of their runs (1), and to prevent build-up of th finer fractions of suspended particles (which could include cysts pathogenic protozoans) within the treatment system which could lead a filter breakthrough with the pathogens entering the distributi system (2).

12. Condition Nos. 14, 15 and 16, related to the flow metering, sampling and monitoring program and performance report, are imposed to ensure that all pertinent data are available for the water works performance evaluation and to ensure that the water works is operated and maintained at the level consistent with the design objectives, and is effective in producing water of an acceptable quality at all times.

You may by written notice served upon me and the Environmental Appeal Board within 15 days after receipt of this Notice, require a hearing by the Board. Section 63 of the Ontario Water Resources Act, R.S.O. 1980, C. 361, as amended, provides that the Notice requiring the hearing shall state:

1. The portions of the approval or each term or condition in the approval in respect of which the hearing is required, and;
2. The grounds on which you intend to rely at the hearing in relation to each portion appealed.

The Notice should also include:

3. The name of the appellant;
4. The address of the appellant;
5. The Certificate of Approval number;
6. The date of the Certificate of Approval;
7. The name of the Director;
8. The municipality within which the water works are located;

And the Notice should be signed and dated by the appellant.

This Notice must be served upon:

The Secretary,
Environmental Appeal Board,
112 St. Clair Avenue West,
5th Floor,
Toronto, Ontario.
M4V 1N3

AND

The Director,
Section 23, Ontario Water Resources Act,
Ministry of the Environment,
250 Davisville Avenue,
Toronto, Ontario.
M4S 1H2

The above noted water works are approved under Section 23 of the Ontario Water Resources Act.

DATED AT TORONTO this 20th *day of* February, 1992.

THIS IS A TRUE COPY OF
THE ORIGINAL CERTIFICATE
SIGNED BY
W. GREGSON, P. ENG.

MAILED ON FEB 20 1992
BY ________

MT/fn
Attn: Mrs. R. Colquhoun, Clerk, Township of Percy
cc: Mr. J. Janse, MOE C, Acting Reg. Dir.
Totten Sims Hubicki Associates ✓
Director, Water Resources Branch, Attn: K. Roberts

SCHEDULE "A"

This Schedule "A" forms part of Certificate of Approval (Water) No. 7-1535-91-926.

The following is a list of documents containing the information relied upon in the issuance of the Certificate of Approval:

1. Application for Approval of Water Works dated December 16, 1991, signed by Mrs. R. Colquhoun, Administrator-Clerk, Township of Percy.

2. Report entitled "Township of Percy. Police Village of Warkworth. Water Supply System. Design Brief." dated December 1991, prepared by Totten Sims Hubicki Associates.

3. Contract specification document entitled "Township of Percy. Police Village of Warkworth. MOE Project No. 7-0724. Contract No. 1. Water Supply Plant Expansion. Contract Documents." dated January 1992, prepared by Totten Sims Hubicki Associates.

4. Engineering drawings entitled "Township of Percy. Police Village of Warkworth. Water Supply Plant Expansion. MOE Project No. 7-0724-01." prepared by Totten Sims Hubicki Associates, printed on January 27, 1992.

Analytical Procedures used by Maxxam Analytics

Appendix D

Detection Limit and Analytical Method Reference used by Maxxam Analytics

PARAMETERS	MINIMUM DETECTION LIMIT(MDL)	ANALYTICAL METHOD	METHOD REFERENCE*
THM	6 µg/L	Purge &Trap GC/MS	EPA 624
TOC	0.1 mg/L	UV/PEROX/FID	EPA 9060
residual aluminum	0.025 mg/L	ICP	EPA 6010
turbidity	0.1 NTU	Turbidity Meter	APHA 2130
true colour	1 TCU	Colourimetric	APHA 2120
pH	0.01	pH Meter	APHA 4500H
alkalinity	1 mg/L - $CaCO_3$	Titration	APHA 2320
ammonia + ammonium	0.05 mg/L	Colourimetric	APHA 4500
anions (NO_3, Cl, SO_4, F)	0.1 to 0.5 mg/L	Ion Chromatography	EPA 300.0
conductivity	1 umho	Conductivity Meter	APHA 2510
lead	0.002 mg/L	Graphite Furnace	EPA 7421
metals		ICP	EPA 6010
nitrite	0.1 mg/L	Colourimetric	APHA 4500
orthophosphate-P	0.005 mg/L	Colourimetric	APHA 4500

Note * : EPA : Environmental Protection Agency
APHA : American Public Health Association

Evaluation of Residual Chlorine Concentration for Inactivation of Giardia Cysts

Appendix E

E.1 WARKWORTH WATER TREATMENT PLANT

Evaluation of residual chlorine concentration required for 4-log inactivation of giardia cysts for the clearwell 70% full, the plant operated at rated capacity and water temperature of 0.5 °C:

NOTES:

- The SWTR establishes CTs for chlorine, chlorine dioxide, ozone and chloramines which will achieve a min. of 3-log inactivation of giardia cysts. However, it is recommended to use 4-log reduction since there is agricultural activity along the Creek.

- Well operated conventional treatment plants which have been optimized for turbidity removal can be expected to achieve at least a 2.5-log removal of giardia cysts.

CT for 1.5-log inactivation = 146 (at 0.5 °C or lower, pH=8.0 and Conc. = 0.75 mg/L)

Where C = Concentration (mg/L)
T = Contact Time (min)

Evaluation of contact time (T):

T= [Volume of Clearwell (m^3) x %Full x Baffling Condition (T_{10}/T)] / [Maximum Day Flow (m^3/d)] x 1,440 min/d

Volume of Clearwell = 480 m^3
% Full = 0.7
T_{10}/T = 0.5
Rated Capacity 1,232 m^3/d
Temperature = 0.5 °C

T = 196 Minutes

Evaluation of Residual Chlorine Concentration (C):

C = CT for 1.5-log inactivation / T
CT = 146

C = 0.74 mg/L

E.2 WARKWORTH WATER TREATMENT PLANT

Evaluation of residual chlorine concentration required for 4-log inactivation of giardia cysts for the clearwell 70% full, the plant operated at rated capacity and water temperature of 5 °C:

NOTES:

- The SWTR establishes CTs for chlorine, chlorine dioxide, ozone and chloramines which will achieve a min. of 3-log inactivation of giardia cysts. However, it is recommended to use 4-log reduction since there is agricultural activity along the Creek.
- Well operated conventional treatment plants which have been optimized for turbidity removal can be expected to achieve at least a 2.5-log removal of giardia cysts.

CT for 1.5-log inactivation = 100 (at 5 °C or lower, pH=8.0 and Conc. = 0.5 mg/L)

Where C = Concentration (mg/L)
T = Contact Time (min)

Evaluation of contact time (T):

$T = [\text{Volume of Clearwell } (m^3) \times \%\text{Full} \times \text{Baffling Condition } (T_{10}/T)] / [\text{Maximum Day Flow } (m^3/d)] \times 1,440 \text{ min/d}$

Volume of Clearwell =	480 m^3
% Full =	0.7
T_{10}/T =	0.5
Rated Capacity	1,232 m^3/d
Temperature =	5 °C

T = 196 Minutes

Evaluation of Residual Chlorine Concentration (C):

C = CT for 1.5-log inactivation / T
CT = 100

C = 0.51 mg/L

E.3 WARKWORTH WATER TREATMENT PLANT

Evaluation of residual chlorine concentration required for 4-log inactivation of giardia cysts for the clearwell 70% full, the plant operated at rated capacity and water temperature of 10 °C:

NOTES:

- The SWTR establishes CTs for chlorine, chlorine dioxide, ozone and chloramines which will achieve a min. of 3-log inactivation of giardia cysts. However, it is recommended to use 4-log reduction since there is agricultural activity along the Creek.

- Well operated conventional treatment plants which have been optimized for turbidity removal can be expected to achieve at least a 2.5-log removal of giardia cysts.

CT for 1.5-log Inactivation = 75 (at 10 °C or lower, pH=8.0 and Conc.<= 0.4 mg/L)

Where C = Concentration (mg/L)
T = Contact Time (min)

Evaluation of contact time (T):

T= [Volume of Clearwell (m^3) x %Full x Baffling Condition (T_{10}/T)] / [Maximum Day Flow (m^3/d)] x 1,440 min/d

Volume of Clearwell = 480 m^3
% Full = 0.7
T_{10}/T = 0.5
Rated Capacity 1,232 m^3/d
Temperature = 10 °C

T = 196 Minutes

Evaluation of Residual Chlorine Concentration (C):

C = CT for 1.5-log inactivation / T
CT = 75

$\boxed{C = 0.38 \text{ mg/L}}$

E.4 WARKWORTH WATER TREATMENT PLANT

Evaluation of residual chlorine concentration required for 4-log inactivation of giardia cysts for the clearwell 70% full, the plant operated at rated capacity and water temperature of 15 °C:

NOTES:

- The SWTR establishes CTs for chlorine, chlorine dioxide, ozone and chloramines which will achieve a min. of 3-log inactivation of giardia cysts. However, it is recommended to use 4-log reduction since there is agricultural activity along the Creek.

- Well operated conventional treatment plants which have been optimized for turbidity removal can be expected to achieve at least a 2.5-log removal of giardia cysts.

CT for 1.5-log inactivation = 50 (at 15 °C or lower, pH=8.0 and Conc.<= 0.4 mg/L)

Where C = Concentration (mg/L)
T = Contact Time (min)

Evaluation of contact time (T):

T= [Volume of Clearwell (m^3) x %Full x Baffling Condition (T_{10}/T)] / [Maximum Day Flow (m^3/d)] x 1,440 min/d

Volume of Clearwell = 480 m^3
% Full = 0.7
T_{10}/T = 0.5
Rated Capacity 1,232 m^3/d
Temperature = 15 °C

T = 196 Minutes

Evaluation of Residual Chlorine Concentration (C):

C = CT for 1.5-log inactivation / T
CT = 50

C = 0.25 mg/L

E.5 WARKWORTH WATER TREATMENT PLANT

Evaluation of residual chlorine concentration required for 4-log inactivation of giardia cysts for the clearwell 70% full, the plant operated at rated capacity and water temperature of 20 °C:

NOTES:

- The SWTR establishes CTs for chlorine, chlorine dioxide, ozone and chloramines which will achieve a min. of 3-log inactivation of giardia cysts. However, it is recommended to use 4-log reduction since there is agricultural activity along the Creek.

- Well operated conventional treatment plants which have been optimized for turbidity removal can be expected to achieve at least a 2.5-log removal of giardia cysts.

CT for 1.5-log inactivation = 37 (at 20 °C or lower, pH=8.0 and Conc.<= 0.4 mg/L)

Where C = Concentration (mg/L)
T = Contact Time (min)

Evaluation of contact time (T):

T= [Volume of Clearwell (m^3) x %Full x Baffling Condition (T_{10}/T)] / [Maximum Day Flow (m^3/d)] x 1,440 min/d

Volume of Clearwell = 480 m^3
% Full = 0.7
T_{10}/T = 0.5
Rated Capacity 1,232 m^3/d
Temperature = 20 °C

T = **196 Minutes**

Evaluation of Residual Chlorine Concentration (C):

C = CT for 1.5-log inactivation / T
CT = 37

$\boxed{C = \textbf{0.19 mg/L}}$